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EOSDIS Core System Project

Verification Plan for the ECS Project

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Final

June 1994

Hughes Applied Information Systems
Landover, Maryland

Verification Plan
for the
ECS Project

Final

June 1994

Prepared Under Contract NAS5-60000
CDRL Item 063

SUBMITTED BY

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Preface

This document is a formal contract deliverable with an approval code 1. It requires Government review and approval prior to acceptance and use. Changes to this document also require Government approval prior to acceptance and use. Once accepted, changes to this document shall be made by document change notice (DCN) or by complete revision.

This document is under ECS Project Configuration Control. Any questions or proposed changes should be addressed to:

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Abstract

This Verification Plan (DID 401/VE1) presents the overall test, review, and analysis effort for the ECS project, describes the verification activities associated with each ECS life cycle phase and level of verification, delineates the responsibilities of, and interfaces among, those organizations that verify the ECS, and describes verification reporting activities.

Keywords: *acceptance, configuration management, integration, methodology, nonconformance, release, segment, system, test, validation, verification.*

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1. Introduction

1.1 Identification

The Verification Plan, Contract Data Requirements List (CDRL) item 063, whose requirements are specified in Data Item Description (DID) 401/VE1, is a required deliverable under the Earth Observing System Data and Information System (EOSDIS) Core System (ECS), Contract (NAS5-60000).

1.2 Scope

This document defines the overall plan for the verification of the ECS, its segments, and their main components. It applies to all levels of verification throughout the ECS life cycle. Verification activities for the ECS development and operational stages are included, although the emphasis is on the development stage. The roles and activities of all ECS contractor verification organizations, as well as the Government, the EOSDIS Independent Verification and Validation (IV&V) contractor, and the science community, are included. However, the roles and activities of the Government, IV&V contractor, and science community as described herein are for informational purposes only. This document positively does *not* impose any obligations or restrictions whatsoever on the Government, the IV&V contractor, and the science community.

1.3 Purpose and Objectives

This Verification Plan describes the test, review, and analysis effort to be conducted for the ECS. This document presents the overall processes and activities associated with verifying the ECS during all life cycle phases and at all levels of verification. It delineates the roles and responsibilities of each verification organization associated with the ECS project.

1.4 Status and Schedule

This document is the final Verification Plan for SDR due in June 1994. This document will be updated only when major changes in the ECS verification program warrant a revision.

1.5 Document Organization

This document is organized in five sections.

- Section 1, Introduction, describes and identifies the Verification Plan.
- Section 2, Related Documentation, lists relevant documentation as it applies to this Verification Plan.
- Section 3, Verification Overview, summarizes the ECS major functions and project schedule, describes the verification activities associated with multi-track development, ECS releases, evaluation packages (EPs), Product Generation System (PGS) toolkits, and

science algorithms; discusses tools and methodologies; enumerates the responsibilities of the various verification and associated organizations; summarizes resources needed to perform verification activities; and discusses the verification activities associated with each formal release life cycle phase and level of verification.

- Section 4, Verification Reporting, defines verification documentation, coordination activities, and nonconformance reporting and reviewing.
- Section 5, Configuration Management, describes configuration control of test items, release management, and configuration audits.

2. Related Documentation

2.1 Parent Documents

The following documents are the parents from which the scope and content of this document derive:

GSFC	EOSDIS Core System Statement of Work, 2/16/93
GSFC	Earth Observing System (EOS) Performance Assurance Requirements for the EOSDIS Core System (ECS), 5/23/91
GSFC	Earth Observing System Configuration Management Plan, 1/90
216/SE1	ECS Requirements Specification, February 1994

2.2 Applicable Documents

The following documents are applicable to this Verification Plan.

102/MG1	ECS Configuration Management Plan, March 1994
103/MG3	Configuration Management Procedures, October 1993
104/MG1	Data Management Plan, August 1993
107/MG1	Summary Schedule, March 1994
201/SE1	ECS Systems Engineering Plan, May 1993
219/SE1	Interface Requirements Documents
304/DV1	Segment/Element Requirements Specification
305/DV2	Element Design Specification
313/DV3	ECS Internal ICDs
319/DV1	Segment/Element Integration & Test Plan
322/DV3	Segment/Element Integration & Test Procedures
324/DV3	Segment/Element Integration & Test Reports
329/DV2	Segment/Element Development Plans
402/VE1	ECS System Integration & Test Plan
403/VE1	Verification Specification
404/VE1	Procedure for Control of Unscheduled Activities During Verification

405/VE3	ECS System Integration & Test Report
409/VE1	ECS System Acceptance Test Plan
411/VE1	ECS System Acceptance Test Procedures
412/VE2	ECS System Acceptance Test Report
414/VE1	ECS System Integration & Test Procedures
415/VE1	Acceptance Testing Management Plan, October 1993
511/PA1	Maintainability Demonstration Plan
512/PA1	Maintainability Demonstration Test Plans
519/PA3	Maintainability Demonstration Test Reports
535/PA1	Acceptance Data Package
801/SD4	PGS Toolkit Requirements Specification, October 1993

2.3 Information Documents

The following documents, although not directly applicable, amplify or clarify the information presented in this document, but are not binding.

GSFC	Performance Verification Plan for the EOS Data and Information System Core System, 4/20/94
FB9403V1	Release Plan Content Description White Paper, February 1994
194-00110	Science Algorithm Delivery Issues Discussion Paper, January 1994
PI-QO-1-009	Nonconformance Reporting and Corrective Action (NRCA) Project Instruction
PI SD-1-004	Software Inspections Process Project Instruction

3. Verification Overview

This section contains an overview of the ECS verification effort. A summary of ECS capabilities and project schedule, including major functions, multi-track development, ECS releases, EPs, PGS toolkits, and science algorithms, is presented. This is followed by a description of test tools, methodologies, organizational responsibilities, resources, release life cycle activities, and verification levels used in verifying the ECS.

3.1 ECS Functional Overview

The ECS provides the following fundamental capabilities:

- EOS mission operations including the planning, scheduling, commanding, and monitoring of EOS spacecraft and instruments.
- Processing, archival, distribution, and retrieval of data obtained from EOS missions, the Tropical Rainfall Measuring Mission (TRMM), and other earth observing missions.
- Migration of EOSDIS Version 0 data into the ECS.

The ECS is a very large, complex system, that consists of three segments: the Flight Operations Segment (FOS), the Science Data Processing Segment (SDPS), and the Communications and System Management Segment (CSMS).

FOS manages and controls EOS spacecraft as well as on-board instruments. The FOS is implemented at the EOS Operations Center/Instrument Control Center (EOC/ICC), and Instrument Support Terminals (ISTs). The EOC/ICC provides overall mission planning and scheduling as well as command and monitoring of mission operations for EOS spacecraft and on-board instruments. The EOC/ICC controls the following EOS spacecraft, assuming the full complement of spacecraft specified in Change Order #1 is exercised: AM-1, AERO, PM, CHEM, and ALT. ISTs consist of user-provided workstations and ECS software that connects a Principal Investigator or Team Leader to an ICC in support of remote instrument control and monitoring.

SDPS provides archiving, processing, and distribution services for science data and a data information system for the entire EOSDIS. The SDPS processes Level 0 data into Level 1 through 4 data products and provides storage and distribution services for all levels of data. Additionally, the SDPS provides a suite of distributed data services, information management services, and user services.

CSMS provides overall ECS management and operations of the ground system resources, provides facilities and communications/networking services for an extensive science data communications network, and manages the interfaces to National Aeronautics and Space Administration (NASA) communications networks and other networks. The CSMS System Management Center (SMC) provides overall system management of the ECS. The CSMS EOSDIS Science Network (ESN) provides a dedicated, internal ECS communications network for the interconnection of EOSDIS facilities and EOS investigators at their ISTs or Science

Computing Facilities (SCFs). The ESN also provides an interface between the ECS and gateways provided by the NASA Science Internet to external science research networks.

3.2 ECS Schedule

The overall milestone and activity schedule for the ECS is driven by mission launches and science data requirements. The milestones and activities, in turn, drive ECS verification activities, which are described in this document. Key milestones and activities are contained in the ECS Master Schedule (DID 107/MG1). ECS releases, EPs, and PGS toolkits, which are the delivery mechanisms for ECS capabilities and are included in the ECS Master Schedule, have different delivery dates and different verification activities associated with them. They are described in Subsections 3.2.1, 3.2.2, and 3.2.3, respectively.

The ECS develops incrementally through sets of enhanced capabilities employing multiple processes. The two main development approaches, also referred to as “tracks”, are formal development and incremental development. Incremental development is used in those areas of the ECS where requirements are less well understood, while formal development is used where requirements are more stable. The premise behind multi-track development is that these two differing requirement types can best be implemented through differing development processes tailored to their individual needs.

The formal development track is a development process distinguished by a complete tree of requirements documentation, formal reviews at major milestones in the development cycle, and a single waterfall of development cycle phases leading to a formal release. The single waterfall has a long time frame relative to the incremental development track. Most capabilities on the formal track are delivered via releases.

The incremental development track is distinguished by multiple iterations of requirements, design, and implementation with frequent user evaluations via demonstrations. The incremental track involves rapid development of software. Documentation and reviews are streamlined, and documentation of non-mission critical capabilities is prepared after development has completed. Each increment is developed with the potential of being integrated into the formal track via a release. The incremental track has a cycle time of about 9 months, which is considerably less than that of the formal track. Components of the incremental track form a growing baseline of delivered capability that is initially intended for science and engineering user evaluation rather than operational use. These components are deployed to the Distributed Active Archive Centers (DAACs) as part of an EP. The ECS Systems Engineering Plan (DID 201/SE1) describes multi-track development further.

3.2.1 ECS Releases

An ECS release is the sum total of capabilities developed on, as well as capabilities migrated into, the formal development track. There are two types of releases: formal and interim. A formal release is a system-wide update to the ECS that provides major capabilities. Formal releases undergo all levels of verification performed by the ECS contractor, i.e., unit testing, segment integration and test (I&T), system I&T, and acceptance testing. Release acceptance testing is

performed by the Independent Acceptance Test Organization (IATO). Four formal Releases, i.e., Releases A, B, C, and D are currently planned.

An interim release is the delivery mechanism for system capability resulting from early efforts on the formal track for testing ECS functionality prior to an operational version. Interim releases require segment I&T as well as system I&T activities, but no acceptance testing. Interim release capabilities are completely contained in the next formal release. Thus acceptance testing of interim release capabilities is deferred until the formal release is acceptance tested. One interim Release, i.e., Interim Release-1 (IR-1) is currently planned. The Release Plan Content Description White Paper (FB9403V1) describes ECS releases in further detail.

Figure 3-1 depicts the life cycle of a formal release in terms of verification levels and key reviews. The six verification levels, i.e., unit testing, segment I&T, system I&T, acceptance testing, Independent Verification and Validation (IV&V) testing, and operational testing, are described in Subsection 3.7, Verification Levels. Operational testing, unlike the other verification levels, can occur anytime throughout the life of the ECS once operations begin. The ECS reviews included in Figure 3-1 involve reviews of verification-activities that occur during the development life cycle of a formal release. Each review occurs at a critical time during the formal release life cycle and is oriented primarily towards either the system or segment level. For Release A, these reviews are: the System Requirements Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), Test Readiness Review (TRR), Element Test Review (ETR), Consent to Ship Review (CSR), Segment Operational Readiness Review (SORR), and Release Readiness Review (RRR). For Releases B, C, and D, a Release Initiation Review (RIR) replaces the SRR, and an Incremental Design Review (IDR) replaces the PDR. Results of Informal TRRs are used during segment I&T, and results of Informal ETRs are used during system I&T. As portions of system I&T are completed, they are evaluated by the IATO in preparation for acceptance testing. Besides the SRR, the Project Management Review (PMR) and System Design Review (SDR) encompass the entire ECS project, rather than a particular release. Subsection 3.6, Release Life Cycle Verification Activities, describes reviews in further detail.

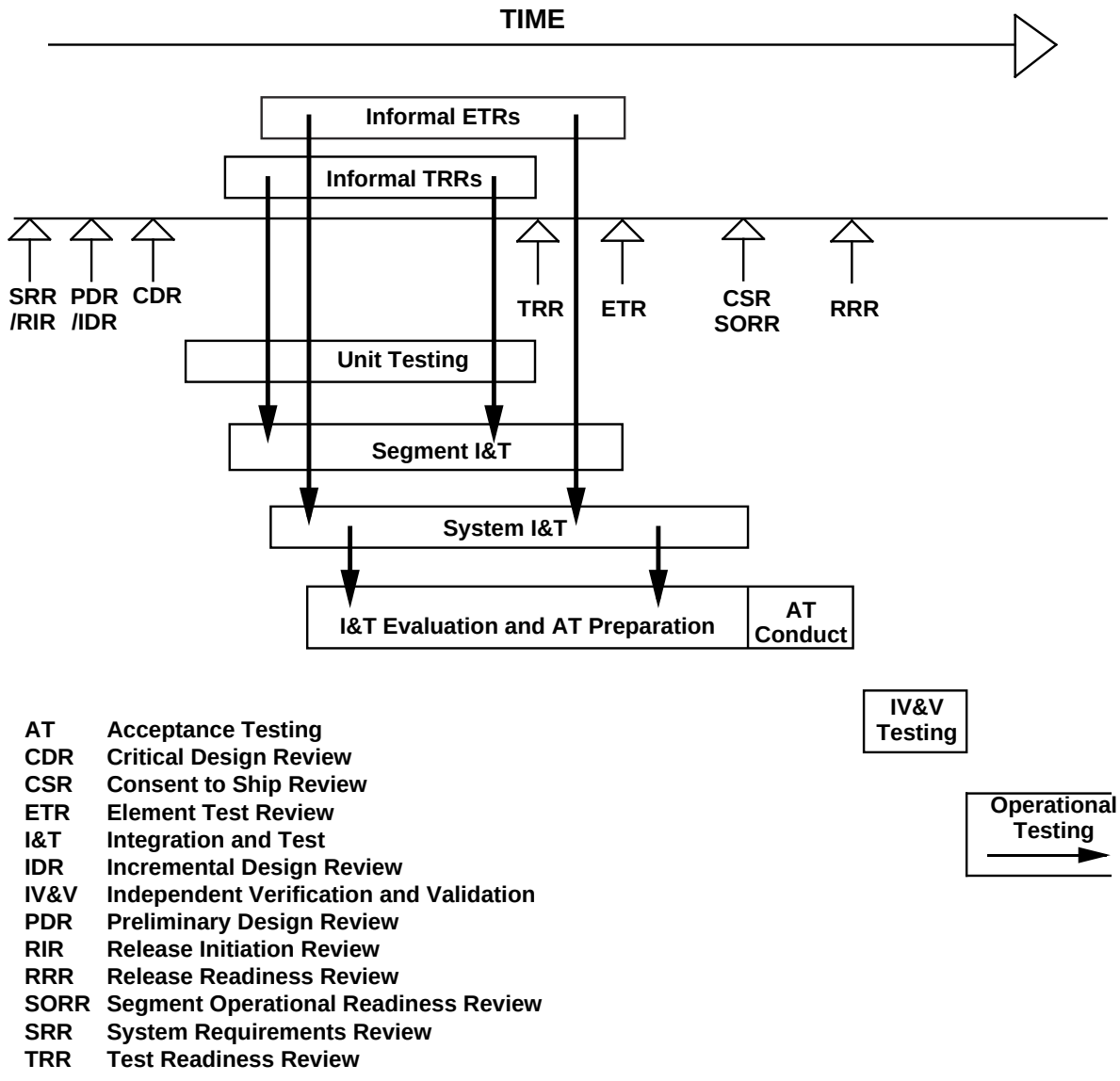


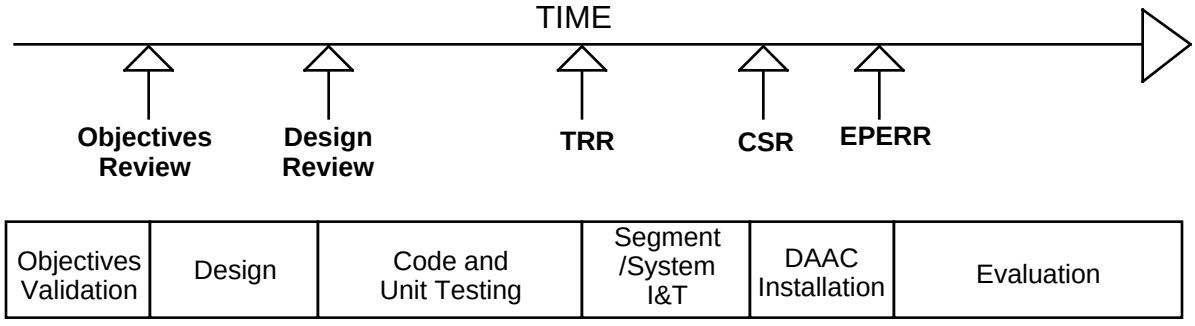
Figure 3-1. Formal Release Life Cycle

3.2.2 Evaluation Packages (EPs)

EPs are the delivery mechanism for ECS capabilities developed on the incremental track and for selected prototypes. EPs deploy incrementally developed functionality and selected prototypes to the DAACs for science and engineering user evaluation rather than operational use. Evaluators provide feedback to ECS developers to guide designs and implementations of later EPs. In this way, each succeeding EP contains more capability than the cumulative capabilities of the previous EPs.

The life cycle of an EP, which spans about nine months, is depicted in Figure 3-2. Following validation and review of EP objectives, the EP is designed, coded, and unit tested. Then a TRR is conducted. This is followed by I&T, which is performed as a joint segment and system I&T effort. A CSR follows I&T to determine if the EP is ready for installation at the DAACs, and if so, if there are any constraints or limitations on this deployment to the DAACs. A demonstration of EP capabilities is conducted at the DAACs and the EDF as part of the Evaluation Package Evaluation Readiness Review (EPERR). Following the EPERR, the EP is evaluated by science and engineering users, who provide EP feedback for incorporation into future EPs, and ultimately, into the formal development track. There is no acceptance testing of EPs since they are intended for user evaluation rather than operational use. However, those EP capabilities that are migrated into the formal track are acceptance tested as part of the formal release that contains these capabilities.

Several criteria must be satisfied before an increment can transition to the formal development track: (1) user feedback must be assessed for possible impacts on the design approach or changes to the requirements; (2) the stability and completeness of the requirements must be confirmed; and (3) all enhancements to documentation, requirements traceability, configuration management, etc. that are needed to comply with formal track specifications must be made prior to transition. An increment that meets these criteria prior to the TRR of the next formal release would be migrated into the applicable release. There is also the possibility that an increment might be incorporated into an interim release. In this latter case, the above criteria must be met prior to the ETR of the interim release. In any case, once migration to the formal development track is accomplished, all verification activities are the same as those of the underlying formal track. The migrated increment capabilities, which were developed for user evaluation on the incremental track, are put into operational use following successful completion of system I&T for interim releases or IV&V testing for formal releases.



CSR Consent to Ship Review
DAAC Distributed Active Archive Center
EPERR Evaluation Package Evaluation Readiness Review
I&T Integration and Test
TRR Test Readiness Review

Figure 3-2. Evaluation Package Life Cycle

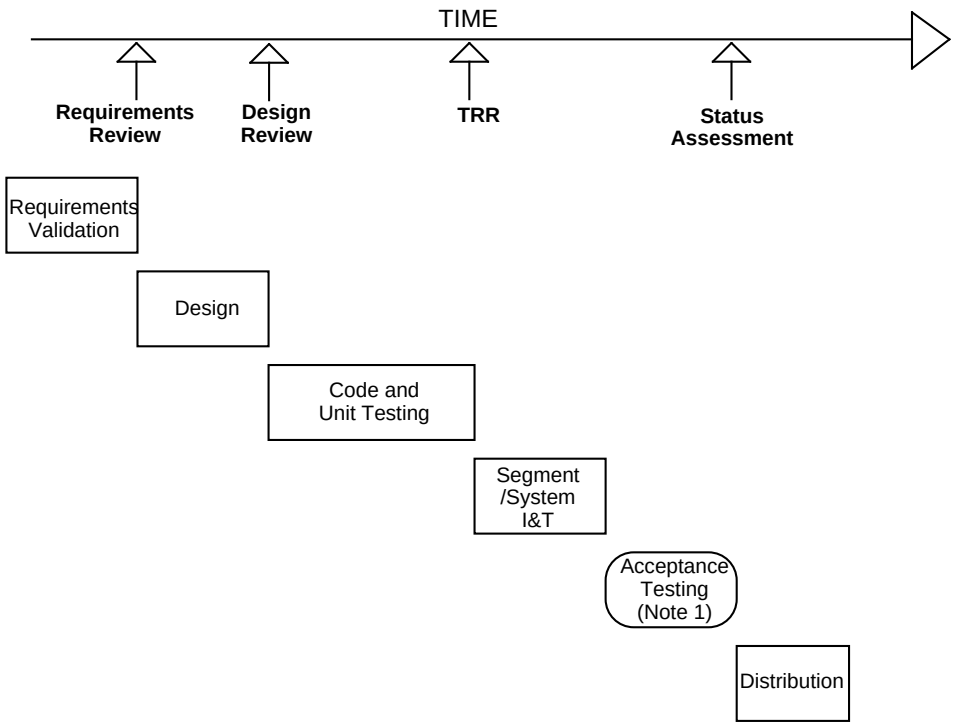
3.2.3 Product Generation System (PGS) Toolkits

PGS toolkits are software packages that facilitate science algorithm development and other science community development activities. These toolkits provide an environment in which algorithms developed at SCFs and destined for operational use within the PGS part of DAACs might be developed and verified. There are two versions associated with these toolkits: an SCF version used in conjunction with developing algorithms and an operational DAAC version. SCF versions are developed, verified, and delivered to the SCFs in several toolkit deliveries to provide early support for science algorithm development, product assurance, and research activities. (Currently five toolkit deliveries to the SCFs are scheduled prior to delivery of Release A.) The SCF versions provide calling sequences to interface with the ECS and common science tools. These SCF versions are verified separately from interim and formal releases by using special algorithms. Figure 3-3 depicts the life cycle of a PGS toolkit (SCF version). The SCF versions follow a different testing model than either interim or formal releases. The SDPS performs unit testing, and segment I&T and system I&T organizations share resources to perform joint segment/system I&T on the SCF versions. Acceptance testing of SCF toolkits beyond the second toolkit delivery has not yet been finalized. All testing for the SCF versions is performed at the ECS Development Facility (EDF).

The operational version is used in integrating science algorithms into the operational PGS at the DAACs. The operational versions incorporate all the functionality of the SCF versions. The operational version of the toolkits is verified and delivered concurrently with formal releases to the extent that these toolkits are available for integration no later than the TRR. The operational version undergoes segment I&T, system I&T, and acceptance testing as an integral part of the formal release. Based on the schedule of five deliveries of SCF versions, the five corresponding operational versions will be included in Release A. Any operational PGS toolkits that are not available for integration into the release by TRR will not be integrated until the next formal release. The PGS Toolkit Requirements Specification (DID 801/SD4) describes PGS toolkits further.

3.2.4 Science Algorithms

Science algorithms are developed by algorithm development teams at the SCFs. The algorithms are destined to be integrated with the PGS portion of the DAACs to process lower level data and generate tailored products for ECS users. The SCFs create three versions of these algorithms: beta version, version 1, and version 2. Reviews of beta version algorithms are generally held between 30 and 36 months prior to launch of the applicable spacecraft instrument. Activities associated with the beta version of the algorithm include exchanging information between the SCF and ECS Algorithm Integration Team (AIT) so that an insight into the algorithm and an understanding of the DAAC operational environment might be obtained, verifying that the prototype and design are compatible with the ECS conceptual architecture, and discussing acceptance test concepts, cases, plans, and structure.



Note 1: Acceptance testing has been skipped on the first two PGS toolkit deliveries.

I&T Integration and Test
TRR Test Readiness Review

Figure 3-3. PGS Toolkit (SCF Version) Life Cycle

Version 1 algorithms, which are considerably more developed than beta versions, are delivered to the applicable DAAC(s) between 20 and 24 months prior to applicable instrument launch. Activities include utilizing the DAAC versions PGS toolkits, testing DAAC PGS interfaces, preparing test plans, evaluating test data, preparing detailed test procedures, integrating the algorithms into the DAAC PGS, and performing informal testing including acceptance testing. These activities are repeated for version 2 algorithms but in a more detailed manner and formal environment than for version 1 algorithms.

Version 2 algorithms, which represent final algorithm development, are delivered to the applicable DAAC(s) between 9 and 12 months prior to applicable instrument launch. I&T activities are much more detailed and formal than for either the Version 1 or Beta version. The AIT, which is part of the ECS contractor but under DAAC supervision, conducts an initial evaluation of the algorithm. The algorithm is then integrated into the DAAC using operational PGS toolkits. The AIT team verifies that the algorithm operates properly in the PGS production environment and that the interfaces required by the algorithm are rigorously tested with the algorithm. However, the science community, not the ECS contractor, verifies the scientific validity of the algorithm itself. The ECS contractor aids the I&T of algorithms with regard to the

DAAC. Following algorithm integration into the PGS, the AIT, rather than the IATO, assists the algorithm development team in performing acceptance testing to determine if the algorithm should be incorporated into the operational DAAC environment. The overall algorithm verification effort at the DAACs entails four major activities:

- Developing tests to fully verify that the algorithm operates properly in the PGS environment
- Integrating the algorithm with the operational DAAC software interfaces
- Performing acceptance testing for DAAC operations (not science validity of algorithms)
- Documenting operational procedures for the algorithm.

For algorithms that will be implemented at multiple DAACs, verification will be performed at each applicable DAAC. Generally, if there are any problems with algorithm execution within the PGS, the algorithm is returned to the algorithm development team for modification. The Science Algorithm Delivery Issues Discussion Paper (194-00110) describes science algorithms further.

3.3 Tools and Methodologies

This subsection identifies the test tools and methodologies employed in the ECS verification effort.

3.3.1 Test Tools

The automated test planning, management, and testing tools are software packages and/or databases that will assist in the development and tracking of test cases, test data, mapping of requirements to threads and scenarios, executing test procedures, and tracking test results. These tools are used to create the required system configuration; generate, collect, or process test data; measure system performance; and simulate an external interface. They include drivers and other developer support capabilities, communications simulators, loggers and other recording devices, and data generation, reduction and analysis programs. ECS test data will consist primarily of input data sets needed to establish known states and simulate system and spacecraft interfaces. Discrete data sets will be integrated using suitable existing data from ECS or other sources and special-purpose data generated for ECS use. Standard data sets will be established, where possible, to make efficient use of test preparation time.

3.3.1.1 Automated Test Tools

Automated test tools are used to facilitate the execution of test procedures. Included in this definition are Graphical User Interface (GUI) Capture/Playback and Remote Terminal Emulators, data generators, and programmable test languages. The GUI emulators, which are referred to as Computer Aided Software Test (CAST) tools, are used to emulate live users. For data generators, simulated data sets from spacecraft instruments, e.g., Clouds and Earth's Radiant Energy System (CERES) and Lightning Imaging Sensor (LIS) instruments on TRMM, will be needed.

For CAST tools, a tool capable of replaying user sessions (for regression testing) and emulating the maximum numbers of users that ECS is required to support concurrently (for performance testing) is needed. A programmable test language, capable of controlling interface simulators and the CAST, is also needed. This language should have some simple command structures, such as "IF/THEN" and "DO WHILE". These automated tools should include data analysis functions, to compare test results to a pre-defined set of expected results. Events should also be able to be triggered based on time.

Several Commercial Off-the-Shelf (COTS) test tools have been reviewed for applicability to the ECS test program. The evaluation of tools has been done jointly by the Segment and System I&T organizations and the IATO. Evaluation and selection of COTS test tools is accomplished in consultation with the Government. Test tool procurement tasks, which span a total of about five months, are depicted in Figure 3-4. The product order for the selected test tool(s) will be issued prior to PDR. Test tool candidates include XRunner and Load Runner from Mercury Interactive Corp., PreVue X from Performance Awareness Corp., Software Test Works from Software Research, Inc., QA Partner from Segue Software, Inc., XSimultest from Qualtrak, and Vista Replay from Veritas Software.

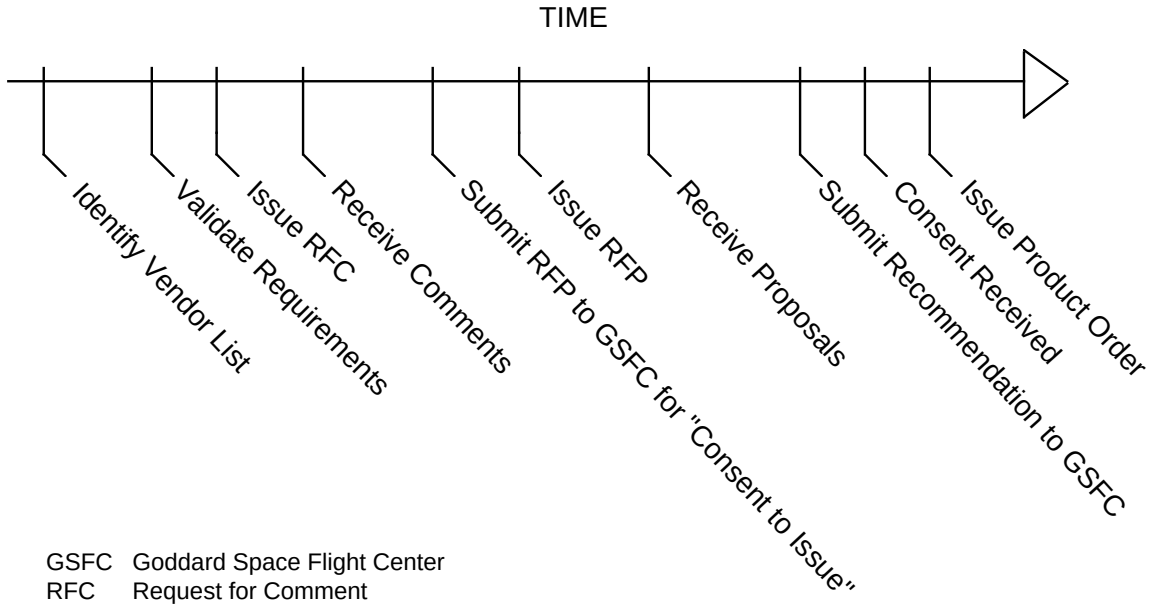


Figure 3-4. Test Tool Procurement Schedule

3.3.1.2 External Interface Simulators

External interfaces are interfaces to systems outside of the scope of the ECS contract (i.e., not developed by the ECS contractor). The interfaces may be to systems already in existence, systems that are being built as a part of the overall Earth Science Data and Information System (ESDIS) project, or systems being built by other Government agencies or other countries. Simulators for external interfaces are computer programs which transmit data in the identical format as the real system. Simulators may be very simple (e.g., canned message transmission) or complex (e.g., dynamic message generation/response). For ECS it is assumed that simulated interfaces will be developed by the ECS project, except to the extent that spacecraft simulators, such as the EOS AM-1 Spacecraft Simulator (SSIM) and the EOSDIS Test System (ETS), are mature and available to provide simulated interfaces.

The FOS interfaces with the SSIM to conduct simulated operations. The SSIM is tentatively scheduled to be available in mid-1997, about one year prior to the launch of the EOS AM-1 Spacecraft. When it is installed, the SSIM will be used for testing EOC/ICC capabilities and for training EOC/ICC personnel. SSIM capabilities include verifying functional capabilities and interfaces between spacecraft and EOSDIS ground elements including the EOC/ICC, and simulating realistic onboard spacecraft functions and reactions to real-time commands. The SSIM models spacecraft subsystems, sensor data, instruments, and mass properties including consumables, ground interfaces, and the orbital environment. The SSIM also processes real-time commands, provides realistic telemetry responses, and supports testing of selected functional and interface capabilities. Additionally, the EOS AM-1 spacecraft vendor would provide high rate science data tapes to perform data flow tests between the EOS AM-1 spacecraft and EOSDIS ground elements.

The primary purpose of the ETS is to support verification of data throughput and system performance. The ETS supports external interface testing and will be geographically distributed. It has limited capability to support fault isolation and functional verification of the EOC/ICC and DAACs.

3.3.1.3 Integration of Tools in the EDF Test Bed

Figure 3-5 provides a conceptual diagram of a system under test, such as an ECS release, and associated tools needed to exercise the system under test. For each release, simulators need to be developed for the applicable external interfaces, e.g., the EOS Data and Operations System (EDOS) and the EOS Communications (Ecom) network. Data generators, or simulated data, will be required to test some aspects of ingest, archive, and distribution of data, especially for Release A, since many of the external systems will be immature and unavailable.

Data Reduction and Analysis Tools are designed to analyze test output data. They include utilities that compare test output data with benchmark data. Some form of a sophisticated file comparison utility will be needed to compare expected results with actual test results. A data reduction utility will also be needed to reduce large amounts of output data, such as output data from the PGS, to some meaningful evaluation of the data quality.

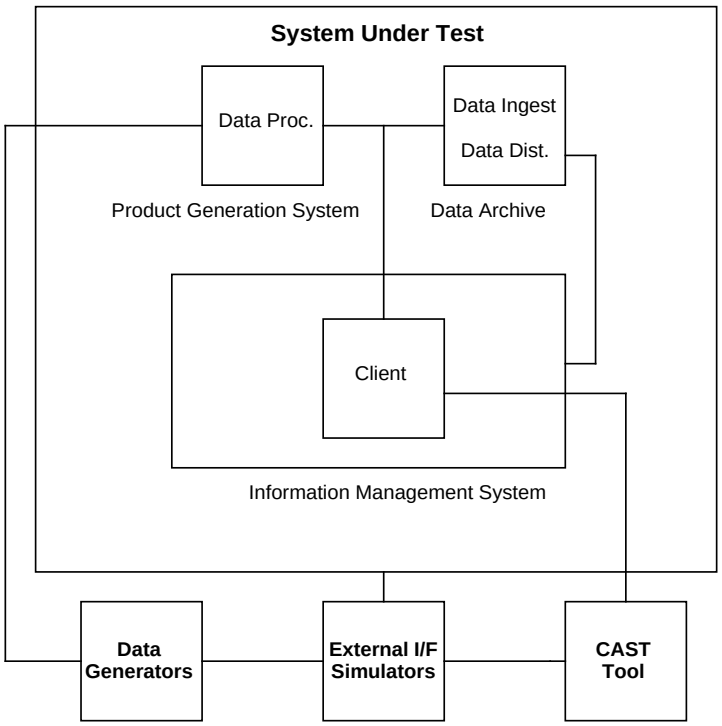


Figure 3-5. Test Tools and Their Integration into the EDF

3.3.1.4 Requirements & Traceability Management (RTM)

The RTM Computer Aided Software Engineering (CASE) tool, although not a test tool, has been selected by the ECS contractor to provide the means for creating, populating, and maintaining a data base containing requirements, verification, and design information. RTM provides the data base for mapping Level 3 requirements to test scenarios and test cases. It contains attributes such as requirement identifier, requirement text, requirement priority, applicable release(s), verification method, test scenario identifier, test case number, and verification status.

3.3.2 Verification Methodologies

The ECS verification program employs an organized approach to unit testing. For I&T, a build/thread methodology is used, while for acceptance testing, a science and operations scenario methodology is employed. Additionally, the verification program utilizes four methods of verifying requirements and analysis of test results.

3.3.2.1 Unit Testing Approach

As coding for each computer software unit (CSU) is completed, the CSU is tested to ensure that its allocated requirements (i.e., the requirements allocated up through the next release) are satisfied. The software developer responsible for the CSU develops a set of step-by-step test procedures, conforming to the standards specified in the General Unit Test Plan, to verify that the

requirements are satisfied. These unit test procedures are placed in the respective Software Development File (SDF) for review by the software development team leader. The software developer conducts the unit test to verify the functionality of the unit and the contents of the test procedures. The results of the unit test will are also placed into the respective SDF for review by the software development team leader. Representatives from the Quality Office are invited to monitor unit testing and to audit the test procedures and results contained in the SDFs. Additional information concerning unit testing is provided in the Segment/Element Development Plans (DID 329/DV2).

3.3.2.2 Build/Thread Methodology

The build/thread concept, which is based on the incremental aggregation of functions, is used to plan the segment I&T and system I&T of the ECS. A thread is the set of components (software, hardware, and data) and operational procedures that implement a function or set of functions. Threads are tested individually to facilitate requirements verification and to isolate problems. A build is an assemblage of threads to produce a gradual buildup of system capabilities. This orderly progression of combining lower level software and/or hardware items to form higher level items with broader capability is known as integration. Builds are combined with other builds and threads to produce higher-level builds. Verification of threads and builds is accomplished at progressively higher and higher levels as the release is assembled.

The build/thread approach provides two levels of integration and testing. First-level testing, performed by the Segment I&T organizations, validates consistency to the designs and assigned functionality of segments and their components. Second-level testing, performed by the System I&T organization, combines segment-level builds/threads into a system release and validates ECS design against overall requirements and user needs. Verifying segment builds and threads starts prior to system-level build/thread verification, since system I&T builds upon the incremental output of segment I&T. However, both levels are performed simultaneously during most of the build/thread process.

The following documents provide more information on build/thread test development, conduct, and results: the Segment/Element Integration & Test Plan (DID 319/DV1), Segment/Element Integration & Test Procedures (DID 322/DV3), Segment/Element Integration & Test Reports (DID 324/DV3), ECS System Integration & Test Plan (DID 402/VE1), ECS System Integration & Test Report (DID 405/VE3), and ECS System Integration & Test Procedures (DID 414/VE1).

3.3.2.3 Science and Operations Scenario Methodology

Acceptance testing utilizes the expertise of the science community and the Maintenance and Operations (M&O) organization in developing science and operations scenarios to verify the ECS Level 3 requirements. In planning for acceptance testing, the IATO utilizes scenarios from the science community via the user modeling process and through the ECS Contractor Science Office. Ideas on operational scenarios are also solicited from the M&O organization. Test scenario candidates are reviewed and refined, as necessary, by the IATO. The IATO, in consultation with the GATT, incorporates the resulting scenarios into the ECS System Acceptance Test Plan (DID 409/VE1) and the ECS System Acceptance Test Procedures (DID 411/VE1).

3.3.2.4 Verification Methods

Four standard verification methods are used to verify the ECS: inspection, analysis, demonstration, and test.

- Inspection. The visual, manual examination of the verification item and comparison to the applicable requirement or other compliance documentation, such as engineering drawings.
- Analysis. Technical or mathematical evaluation based on calculation, interpolation, or other analytical methods.
- Demonstration. Observation of the functional operation of the verification item in a controlled environment to yield qualitative results without the use of elaborate instrumentation, procedure, or special test equipment.
- Test. A procedure or action taken to determine under real or simulated conditions the capabilities, limitations, characteristics, effectiveness, reliability, or suitability of a material, device, system, or method.

The distinction between the demonstration method and the test method is subtle. The emphasis regarding the *demonstration* method is on *observing* the operation of a verification item that is primarily *qualitative*. The emphasis regarding the *test* method is on *executing* a verification item that yields *quantitative* results. The demonstration method usually does not require the use of elaborate instrumentation or special test equipment and does not necessarily generate output data or quantitative results. For COTS hardware and those COTS software products used in the hardware support environment, such as operating systems, demonstration is the most common verification method. The test method always generates quantitative results, including null results. The success/failure of a verification item associated with the demonstration method can be determined by simple observation of the qualitative results. For the test method, the pass/fail criteria requires, as a minimum, a quantitative comparison.

For a given requirement and verification level, multiple verification methods might be employed. The method(s) chosen is (are) determined by the nature of the requirement and the cost/time involved. Inspection is the least complex, least expensive method. Furthermore, the cost differential between methods becomes more pronounced as components are integrated and verification progresses from the informal unit level to the formal acceptance level. These levels are described in Subsection 3.7, Verification Levels.

3.3.2.5 Post-Test Analysis

Post-test analysis includes data reduction and comparison of actual results against expected results. These analyses are accomplished primarily by those organizations responsible for executing the respective tests, e.g., the Segment I&T organizations perform post-test analyses for segment I&T, the System I&T organization for system I&T, and the IATO for acceptance testing. All data reduction output is reviewed for completeness and consistency and recorded for configuration management (CM) control. Materials used to document results, identify possible anomalies, and provide a basis for anomaly resolution include test output, logs and other records of events, nonconformance reports, data reduction material, quality records, and records of other test sessions.

3.4 Verification Responsibilities

Many organizations, including the ECS contractor, the Government, and the IV&V contractor, partake in ECS verification activities. Specifically, verification tasks are performed by the three Segment Development organizations, the three Segment I&T organizations, the System I&T organization, the IATO, the M&O organization, the Quality Office, the Configuration and Data Management organization, the Science Office, the GATT, and the IV&V contractor. Figure 3-6 shows the organizational relationship between these groups. There is a separate Segment Development organization for each of the three segments: CSMS, SDPS, and FOS. These Segment Development organizations are typically divided into lower-level teams. Additionally, the three segments each have a separate organization dedicated to the segment I&T function.

Table 3-1 depicts the primary verification role of each organization for the ECS development and operations stages. The organizations are mapped to the six verification levels, which are shown as column headings in Table 3-1. The verification levels, which correspond to an increase in scope from unit testing of individual modules to operational testing, are described in Subsection 3.7.

The Segment Development organizations perform unit testing of newly developed and heritage software, as well as those COTS software products that are incorporated into segment software and are not an integral part of the hardware support environment. Following unit testing, the Segment I&T organizations perform integration and test activities up to and including the segment level. The System I&T organization integrates and tests all system-level functionality for an entire release. The IATO performs acceptance testing of formal releases and witnesses, monitors, and supports other verification activities. The M&O organization performs unit-level verification of COTS hardware and those COTS software products used in the hardware support environment, such as operating systems. The M&O organization and Science Office assist I&T of algorithms. M&O personnel support the efforts of other verification organizations and maintain the operational system by verifying changes during the M&O phase. Additionally, the M&O organization provides a high level of operational support to acceptance test planning, scenario development, and conduct. The M&O organization also performs verification activities in support of specific flight missions. The Quality Office monitors and witnesses tests and ensures that procedures are followed and nonconformances are correctly documented. The Configuration and Data Management organization provides baselined items for accomplishing most levels of testing, and they support configuration audits. The Science Office provides the IATO with science scenario candidates obtained from the science community. The GATT provides oversight of IATO activities and monitors tests at other levels as desired. The IV&V contractor performs an independent assessment of the functionality and performance of ECS releases.

The following subsections list the verification and validation activities performed by each of these organizations.

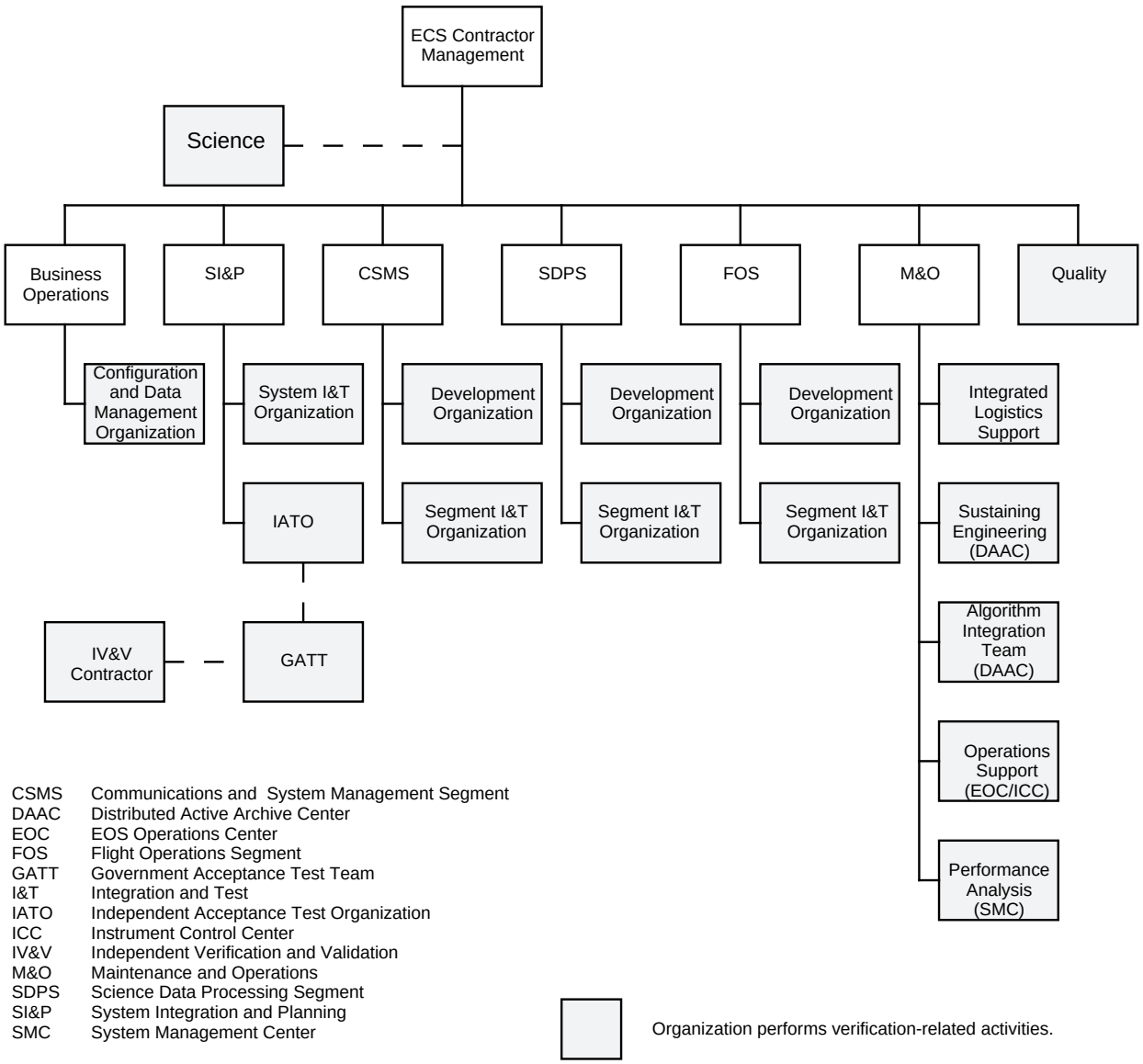


Figure 3-6. ECS Verification Organizations

Table 3-1. Primary Verification Roles

	Development				Operations	
	Unit Testing	**Segment I&T**	**System I&T**	**Acceptance Testing**	**IV&V Testing (Pre-Operational)**	**Operational Testing**
Segment Development Organizations	Perform (software)	Support				
Segment I&T Organizations	Monitor	Perform	Support			
System I&T Organization		Witness	Perform	Support		
IATO	Monitor	Witness	Witness	Perform	Support	Support
M&O Organization	Perform (hardware)	Support	Support	Support	Support	Perform
Quality Office	Monitor	Monitor	Monitor	Witness		Monitor
Configuration and Data Management Organization	Support	Support	Support	Support		
Science Office				Support		
GATT			Monitor	Witness	Monitor	Monitor
IV&V Contractor				Witness	Perform	

3.4.1 Segment Development Organizations

- Verify CSUs and computer software components (CSCs) during unit testing.
- Verify those COTS software products that are incorporated into segment software and are not part of the hardware support environment.
- Document unit test activities in SDFs.
- Work with the Segment I&T organization to support segment-level I&T.

3.4.2 Segment Integration & Test Organizations

- Plan segment I&T tasks and maintain segment I&T procedures.
- Accept unit-tested software, i.e., CSUs and CSCs, from the Segment Development organizations and review SDFs at TRRs.
- Incrementally integrate CSUs, CSCs and COTS products into segment threads to isolate errors, faults, and failures and to verify Level 4 requirements.
- Aggregate segment-level threads into segment-level builds.

- Conduct testing of segment-level threads and builds.
- Test functions as components are added to segment configurations with a focus on internal interfaces.
- Conduct intra-segment interface verification.
- Initiate nonconformance reports.
- Re-verify changes resulting from nonconformance reports.
- Report segment I&T results.
- Perform regression testing on those items that should remain unchanged.
- Work with the System I&T organization to support system-level I&T.

3.4.3 System Integration & Test Organization

- Plans system I&T tasks and maintains system I&T procedures.
- Monitors activities of the Segment I&T organizations including test planning.
- Witnesses segment I&T.
- Accepts segment-level builds from Segment I&T organizations at ETRs.
- Aggregates system-level threads into system-level builds.
- Conducts testing of system-level threads and builds.
- Tests functions as segment components are added to the system configuration to verify performance and isolate anomalies.
- Conducts inter-segment, i.e., intra-ECS, interface verification.
- Conducts informal external interface testing, i.e., testing between ECS and non-ECS systems, using simulators and test data.
- Initiates nonconformance reports.
- Re-verifies changes resulting from nonconformance reports.
- Reports system I&T results.
- Performs regression testing on those items that should remain unchanged.
- Works with the IATO in support of acceptance testing.

3.4.4 Independent Acceptance Test Organization (IATO)

- Receives oversight on acceptance testing from the GATT, since the IATO performs acceptance testing on behalf of the GATT. (The IATO receives direction from the SI&P as part of the ECS contractor team.)
- Defines and maintains ECS acceptance test requirements and acceptance criteria.
- Develops and maintains requirements checklists and requirements traceability and verification matrices.

- Evaluates the testability of risk mitigation/contingency actions.
- Develops acceptance test plans.
- Monitors unit-level verification of COTS hardware and those COTS software products used in the hardware support environment, such as operating systems.
- Identifies those Level 3 requirements that can be verified at the acceptance level through analyzing the results of segment and system I&T.
- Works closely with the Segment and System I&T organizations in planning portions of segment and system tests, whose results the IATO will analyze.
- Witnesses segment I&T.
- Defines and maintains acceptance test procedures.
- Witnesses system I&T.
- Accepts the integrated release from the System I&T organization at CSR.
- Evaluates adherence of delivered ECS systems to Open Systems standards.
- Conducts release acceptance testing to evaluate each ECS release against acceptance test requirements and acceptance criteria.
- Conducts external interface testing with operational or developed systems only if they are mature and available; otherwise, simulators or test data are used.
- Evaluates that the system operates as required to support science data processing and analysis objectives.
- Initiates nonconformance reports.
- Determines the impact of nonconformance reports on test plans, scenarios, cases, and procedures.
- Re-verifies changes resulting from nonconformance reports.
- Reports acceptance testing results.
- Maintains inspection reports.
- Performs regression testing on those items that should remain unchanged.
- Serves as the primary ECS contractor point of contact for the IV&V contractor.
- Ensures that the IV&V contractor has complete and open access to all ECS contractor test activities and technical information for review and analysis including:
  - Plans, procedures, and results of all I&T and acceptance tests including ECS contract deliverables.
  - All nonconformance reports contained in the Nonconformance Reporting and Corrective Action (NRCA) system .
- Ensures that inputs to IV&V schedules are provided to the IV&V contractor.

- Clarifies ECS design, implementation, integration, and test issues for the IV&V contractor.
- Attends EOSDIS Verification and Validation meetings.
- Reviews IV&V test plans and procedures submitted to the ESDIS project.
- Coordinates schedules for technical reviews, system installation, and system testing with the IV&V contractor.
- Ensures adequate ECS contractor personnel and equipment support during IV&V test activities.
- Provides personnel, facilities, and equipment support in the resolution of ECS nonconformances identified during IV&V contractor testing.

3.4.5 Maintenance & Operations Organization

- Accepts IATO-verified releases at RRR.
- Supports the IATO and IV&V contractor, as necessary, during IV&V testing.
- Performs verification of corrections implemented during the M&O phase.
- Performs regression testing on those delivered items that should remain unchanged.
- Maintains vendor-supplied test records and documents for hardware.
- Identifies COTS product test equipment and verifies calibration status.
- Performs unit-level verification of COTS hardware and those COTS software products used in the hardware support environment, such as operating systems.
- Documents COTS product nonconformances.
- Offers operational scenario candidates for acceptance testing to demonstrate expected capability.
- Supports the IATO's acceptance test preparation at the EDF.
- Supports release pre-acceptance testing checkout and formal release acceptance testing at the operational centers, i.e., the DAACs, EOC/ICC, and SMC.
- Assists in algorithm I&T at DAACs.

3.4.6 Quality Office

- Assists in identifying training needs of test personnel and schedules formal training.
- Conducts a CDR traceability audit to confirm that all upper tier requirements are allocated to specific test cases.
- Conducts requirements traceability audits during the Implementation and Integration and Test phases as each test case is completed and evaluated.
- Performs audits of unit test plans and results as part of SDFs.
- Monitors hardware inspection and unit-level verification procedures.

- Verifies results of hardware inspections, analyses, demonstrations, and tests.
- Verifies segment and system test plans for completeness.
- Monitors segment-level and system-level tests to ensure that procedures are followed or defined and that nonconformances are documented.
- Validates segment and system integration tests and test results.
- Participates in segment test implementation, reviews, and analysis.
- Verifies the completeness and currency of the ECS overall test matrix.
- Witnesses formal release acceptance tests.
- Participates in Functional Configuration Audits (FCAs) and Physical Configuration Audits (PCAs) for formal release acceptance tests.
- Maintains the NRCA system for software items that failed to meet expected results.
- Ensures completeness and clarity of nonconformance reports.
- Tracks the status of nonconformance reports.
- Reviews nonconformance reports prior to closure to ensure that all required actions have been completed.
- Extracts metric data from nonconformance reports and other observations to monitor process and product quality and achieve improvements.
- Participates in the final decision on product acceptability.

3.4.7 Configuration and Data Management Organization

- Catalogs and maintains test documents including test plans, procedures, and reports.
- Documents and maintains test environment drawings, which are used internally and are deliverable as part of formal test documentation.
- Captures the test configuration of software, hardware, test data, test tools, and documentation prior to test execution to ensure repeatability.
- Provides testing organizations with controlled software, test data, documentation, and configuration information.
- Supports IATO through all testing.
- Captures and retains test outputs, e.g., test logs, data, and modified procedures, and distributes copies for test analyses.
- Supports FCAs and PCAs.
- Maintains the product baseline, which is established prior to the RRR and includes test reports.

3.4.8 Science Office

- Provides the IATO with scenario candidates obtained from the science community via the user modeling process.
- Assists in algorithm I&T at DAACs.

3.4.9 Government Acceptance Test Team (GATT)

- Oversees activities of the IATO, who performs acceptance testing on behalf of the GATT.
- Reviews test plans, procedures, benchmark tests, analyses, and reports developed by the ECS contractor.
- Witnesses acceptance testing and other testing levels as desired.
- Independently assesses the acceptability of each release.

3.4.10 EOSDIS Independent Verification and Validation (IV&V) Contractor

- Witnesses and monitors ECS contractor verification activities, as desired.
- Uses the IATO as the conduit for all activities regarding the ECS contractor, its activities and deliverables.
- Conducts IV&V tests at ECS operational centers following RRR.
- Validates ECS Level 3 requirements.
- Tracks and facilitates the resolution of nonconformances identified during IV&V testing of the ECS.
- Performs EOSDIS certification testing.

3.5 Verification Resources

This subsection describes the testing facilities, testing positions, and training of test personnel.

3.5.1 Testing Facilities

Verification activities occur at both the EDF and the ECS operational centers, i.e., the DAACs, EOC/ICC, and SMC. The EDF includes a representative set of hardware similar to the hardware to be installed at operational centers. The following verification activities are conducted at the EDF:

- Unit verification of relatively small, common hardware units, such as personal computers, and widely used COTS software, such as word processors. (Due to the small size and large quantity of these items, it is generally more cost effective to perform unit verification at the EDF prior to shipping these items to the operational centers.)
- PGS toolkit verification
- EP I&T and readiness review demonstration

- Unit testing of newly developed and heritage software
- Segment I&T
- System I&T
- Release acceptance test preparation

The following verification activities are conducted at the operational centers indicated:

- EPERR demonstration (DAACs)
- Unit verification of large, complex hardware units, such as super computers, and those COTS software products used in their support environment, such as operating systems. (Due to the large size and complexity of these items, it is generally more cost effective to ship them from the vendor directly to the operational centers for installation and unit verification.) (DAACs, EOC/ICC, and SMC)
- Pre-CSR installation (DAACs, EOC/ICC, and SMC)
- Formal release acceptance testing (DAACs, EOC/ICC, and SMC)
- Verification of corrections and upgrades performed by the M&O team during ongoing operations (DAACs, EOC/ICC, and SMC)
- Algorithm integration testing (DAACs)
- Testing of ECS capabilities, primarily FOS, in support of specific flight missions (EOC/ICC).

3.5.2 Testing Positions

The ECS contractor's verification efforts become more formalized as the verification level progresses from unit testing to release acceptance testing. (Subsection 3.7 describes these verification levels.) The more formal verification levels, such as acceptance testing, utilize more testing positions. Five testing positions are used in verifying the ECS: test participants, test witnesses, test monitors, test conductor, and test manager.

- Test Participants. Individuals who execute the test session. They include test team members, existing computer operators, and other personnel who perform activities related to test conduct, as well as personnel at other facilities that support ECS testing. Each participant is responsible for reviewing the status of materials under his or her control and for reporting this status to the test conductor or lead test participant prior to the start of the test session.
- Test Witnesses. Individuals required or invited to directly observe test conduct to verify compliance with requirements. They include the GATT, IV&V personnel, Quality Office, and others as approved by the Government I&AT Manager. Witnesses do not participate directly in the test activities of a test session. The test manager, test conductor, or lead test participant, as appropriate, is the witnesses' point of contact while a test session is in progress.
- Test Monitors. Individuals who review test data, materials, results, and documentation, but need not be physically present during test conduct.

- Test Conductor. Responsible for all activities associated with a test session and directs test conduct in all respects. Prior to the test session, the test conductor schedules the required test resources, including equipment and facilities; verifies the schedule and notifies participants of any changes; and ensures that the required test materials are complete. The test conductor, in consultation with the test manager (if applicable), schedules and chairs the pretest briefing and assigns follow-up actions as required to ensure that all is ready prior to the test session. During the test session, the test conductor establishes and verifies the system configuration, assigning specific roles to test participants and directing the sequence of events. The test conductor is also responsible for ensuring that all necessary validation activities have been completed. When all test activities are complete, the test conductor coordinates an orderly shutdown of the test system, supervises collection of output and other test materials, and conducts the post-test briefing. If no test conductor is scheduled or present, the lead test participant performs the required tasks.
- Test Manager. Chairs the overall testing activity to ensure that the objectives are clear and to coordinate the sequence of activities with the test conductor. If no test manager is scheduled or present, the test conductor performs the required tasks.

Each verification level uses its own set of testing positions. For example, unit testing requires test participants and monitors. The segment I&T verification level requires more rigorous testing and witnessing than unit testing. System I&T adds a test conductor to the verification effort. Acceptance testing might utilize a test manager as well as participants, witnesses, monitors, and conductors.

3.5.3 Training

The Quality Office assists in identifying training needs of test personnel and schedules formal training. Three verification courses have been identified for the ECS project: a Software Test course, a Software Unit & Integration Test course, and a Software System Testing course. Additionally, selected test personnel attend relevant courses, such as a Software Reviews course, a C-language course, and Object Oriented Analysis/Design courses.

Following selection and validation of test tools, test personnel receive instruction and hands-on training on the use of these tools. Initial training is provided by test tool experts or instructors and consists of either a short period of instruction with demonstration at the EDF, or a formal training class at the EDF or vendor facility with a period of hands-on training conducted during installation of tools. Those personnel who do not receive training by vendor-provided instructors receive instruction and hands-on training by those ECS test personnel who have received instruction and have hands-on experience with the tools. Additionally, a course on I&T tools has been identified.

3.6 Release Life Cycle Verification Activities

Verification activities occur throughout the life cycle of each ECS formal release. The release life cycle is divided into six phases, which are concept definition, system analysis, design, implementation, integration and test, and maintenance and operations. Since releases frequently overlap, multiple phases often occur simultaneously within the overall ECS project. The

activities associated with each release life cycle phase are described in the following subsections. Figure 3-1 depicts key verification efforts in the life cycle of a formal release e.g., Release A. This life cycle model does not apply to PGS toolkits, science algorithms, or EPs.

3.6.1 Concept Definition Phase

The Concept Definition phase extends from the start of release development to the resolution of discrepancies from SRR (for Release A) and RIR (for subsequent releases). Verification activities during this phase for Release A have included the IATO's developing the outline for the Verification Plan (DID 401/VE1) and the preliminary Acceptance Testing Management Plan (DID 415/VE1) (ATMP) for the PMR. The IATO continued developing these documents later in this phase for Release A. In preparation for the SRR, which is conducted only during the Release A cycle, the IATO and System I&T established the overall approach to ECS verification and evaluated ECS Level 3 requirements for testability and understandability, with emphasis on Release A. They will perform a similar evaluation for requirements allocated to Releases B through D in preparation for the respective RIRs, which are release-specific equivalents of the SRR.

Since the start of the Concept Definition phase for Release A, the IATO, System I&T, Segment I&T, Quality Office, and other verification organizations have held regular meetings and established informal working groups to foster understanding, discuss roles, and share and gather information among the various verification organizations. The ECS System Integration & Test Plan (DID 402/VE1), the ECS System Acceptance Test Plan (DID 409/VE1), and the Verification Specification (DID 403/VE1) were begun during the Concept Definition phase for Release A and will be expanded during subsequent releases.

3.6.2 System Analysis Phase

The System Analysis phase encompasses the period of system architecture trade studies and analysis. For Release A, this phase includes the development of the overall ECS high-level design, the SDR preparations, and the resolution of resulting discrepancies. For subsequent releases, it includes the development and resolution of the release-specific high-level design. During this phase for each release, verification methods and science and operations scenarios are identified and mapped to Level 3 requirements. This mapping is maintained in the RTM data base. The Level 3 requirements, release, verification method, and test case are extracted from the RTM data base and included in the Verification Specification (DID 403/VE1). The ECS System Acceptance Test Plan (DID 409/VE1) describes system acceptance test criteria.

System and acceptance-level test plans are prepared, and test plans for segment-level testing are initiated. The IATO completes the final ATMP (DID 415/VE1) and Verification Plan (DID 401/VE1). These two documents do not contain release-specific information and thus will be reissued only when major updates are required. For SDR, the IATO completes the acceptance test plan overview and preliminary information on the Release A portion of the ECS System Acceptance Test Plan (DID 409/VE1). Similarly, the System I&T organization completes the system I&T plan overview and preliminary information on the Release A portion of the ECS System Integration & Test Plan (DID 402/VE1). The Release A part of the Verification Specification (DID 403/VE1) is also prepared for SDR. These latter three documents are release

dependent and are updated during subsequent releases to include information not available during the development of previous releases. The System Design Specification (DID 207/SE1) is inspected as indicated in the ECS Project Instruction for the Software Inspections Process (PI SD-1-004).

3.6.3 Design Phase

The Design phase includes the period of segment detailed design from PDR/IDR preparations to CDR. During this phase, Segment and System I&T organizations allocate segment and system-level threads to segment and system-level builds, respectively. The high-level logical design and low-level physical design of hardware and those COTS software products used in the hardware support environment, such as operating systems, are completed during the design phase. Additionally, the Element Design Specifications (DID 305/DV2) and Segment/Element Detailed Design Specifications (DID 306/DV1) are inspected as indicated in the ECS Project Instruction for the Software Inspections Process (PI SD-1-004).

For each release, system and acceptance-level test procedures are initiated, and segment-level test plans are developed and completed. Test tools are procured (if commercially available), or designed and developed. The Segment I&T organizations develop the overview and Release A portion of the Segment/Element Integration & Test Plan (DID 319/DV1) for the PDR, which occurs only during the Release A cycle. These plans are updated with release-specific information for the respective IDR for Releases B, C, and D. The IATO outlines acceptance test cases and identifies Level 3 requirements that could be verified by IATO analysis of segment I&T results for these requirements. (See Subsection 3.7.2, Segment Integration and Test.) Such requirements would not be acceptance tested at the operational centers.

3.6.4 Implementation Phase

The Implementation phase includes the period covering TRRs and ETRs. During this phase for each release, unit and segment tests are conducted, system I&T is initiated, and acceptance test preparation begins. Additionally, COTS hardware and COTS software are verified as a unit during this phase. Verification that the code implements the design is performed during the Implementation Phase.

The Segment Development organizations verify newly developed and heritage CSUs and CSCs. As software and hardware items complete unit testing, the Segment I&T organizations incrementally assemble lower-level functionality into progressively higher levels until ultimately a segment is completely integrated and tested. Functional components that are integrated are threads, and the result of combining threads is a build (see Subsection 3.3.2.2, Build/Thread Methodology). The Segment I&T organizations verify Level 4 requirements and that intra-segment interfaces function properly.

Segment-level TRRs are conducted for all segment-level threads to be tested for Releases A, B, C, and D. The TRR for each segment is treated as a series of informal reviews culminating in a formal summary review. Each TRR part or session reviews the test readiness of that portion of the segment to be integrated and tested. The final, formal TRR session reviews the test readiness of the entire segment. A TRR session is conducted only after all the components required for thread integration have completed unit testing, the test procedures have been written, and the

components have been prepared for segment I&T. The TRR determines that the Segment/Element Integration & Test Procedures (DID 322/DV3) are complete for the upcoming test session, that these procedures comply with the corresponding test plans, and that the Segment I&T organizations are prepared for segment I&T.

Segment-level ETRs are conducted for each segment following completion of portions of segment-level I&T. Like the TRR, the ETR for each segment is treated as a series of informal reviews culminating in a formal summary review. Each ETR session reviews the results of that portion of the segment just integrated and tested. The final, formal ETR session reviews the I&T results of the entire segment and culminates the Implementation phase. The reviews ensure that segments tested meet segment requirements and that components of segments are properly integrated into segments. The Segment I&T organizations prepare the Segment/Element Integration & Test Reports (DID 324/DV3) for each segment.

The System I&T organization utilizes the ECS System Integration & Test Procedures (DID 414/VE1) for those system I&T activities to be performed between the current ETR session and the next ETR session. The System I&T organization monitors the development process to assess progress toward system stability and to ensure that the previously formulated test plans correctly reflect the system being built. The System I&T organization witnesses segment I&T and monitors nonconformances to assess system maturity. As portions of segments become available for further testing, the System I&T organization begins incrementally testing and integrating system-level threads and builds. This allows logically integral parts of a release to proceed to system I&T as soon as the corresponding parts have completed segment I&T.

During the Implementation phase, the IATO witnesses segment I&T and system I&T, particularly those portions of I&T whose results will be analyzed by the IATO for satisfaction of acceptance criteria. The IATO also develops acceptance test cases and begins release acceptance test preparation as portions of the release complete system I&T. Thus the period of accomplishing acceptance test preparation lags slightly behind system I&T, which in turn lags slightly behind segment I&T. The overlapping of ECS verification efforts provides more time to accomplish segment and system I&T and acceptance test preparation than sequential verification would provide.

3.6.5 Integration and Test (I&T) Phase

The I&T phase begins with the final ETR and ends with the RRR. This phase consists of two major sub-phases: system I&T, performed by the System I&T organization, and formal release acceptance testing, conducted by the IATO.

3.6.5.1 System Integration and Test Sub-Phase

The System I&T organization continues integrating the segment hardware, segment software (newly developed, heritage, and COTS), and data into a working system at the EDF. This is accomplished through the incremental verification of system-level builds and threads. The System I&T organization verifies Level 3 requirements, inter-segment interfaces, and simulated ECS external interfaces. Prior to CSR, the then-current version of the release is installed and at operational centers where the release will become operational. A limited checkout of the release at these centers is performed to provide confidence that the capabilities of the release installed at

the centers are consistent with those at the EDF. All system-level testing is completed prior to the CSR. At the CSR, the System I&T organization presents the results of system I&T. The System I&T organization prepares the ECS System Integration & Test Report (DID 405/VE3).

3.6.5.2 Acceptance Testing Sub-Phase

The IATO continues the acceptance test preparations begun during the Implementation phase. At the CSR, the IATO reviews the results of these acceptance test preparations and the status of the ECS System Acceptance Test Procedures (DID 411/VE1) and presents the schedule and plans for release acceptance testing at the ECS centers. The IATO also presents the acceptance testing approach to ensure that disruptions to ongoing operational services are minimal or nonexistent. A Segment Operational Readiness Review (SORR) is also conducted to review the readiness of each operational center to receive ECS software for a release. The SORR evaluates operational procedures, human interfaces, and equipment and staff readiness. SORR may be held coincident with CSR. Responsibility for the SORR is site management.

Following the CSR and SORR, all items that were baselined at CSR and required for formal release acceptance testing, including plans, procedures, software and data sets used for testing, and software to be tested, are shipped, under CM control, from the IATO portion of the EDF CM library to the IATO portion of the CM library at the required centers. A checkout of the testing environment at operational centers is performed prior to the start of formal release acceptance testing at those centers. The purpose of this checkout is to minimize the risks associated with acceptance testing. The IATO conducts formal release acceptance testing with GATT involvement. M&O and other center personnel support these tests. Acceptance testing verifies ECS Level 3 requirements against acceptance criteria, verifies external interfaces, and validates the content of operational procedures and user guides. The IATO utilizes operational scenarios, solicited from the science community and the M&O organization, for acceptance testing.

The IATO presents the results of acceptance testing at the RRR, which is the last major review involving the ECS contractor. The acceptance test results validate the utility and suitability of the release. The GATT summarizes their assessment of the acceptance testing at the RRR. This review also includes the status of nonconformances, operations guides, user's guides, and other relevant documentation, as well as the status of ECS centers and their interfaces and operations that are affected by the release. Additionally, the approach for installation and operational transition to the new release and the results of FCAs and PCAs supported by the CM organization are presented at the RRR. The Government COTR uses this information presented at the RRR to determine if the release is ready for transition to IV&V and EOSDIS system-level testing. The IATO prepares the ECS System Acceptance Test Report (DID 412/VE2).

3.6.6 Maintenance and Operations (M&O) Phase

The M&O phase extends from RRR to the end of operations for each release. The ECS release is turned over to the M&O organization at the applicable ECS centers at RRR. The release is then made available to the IV&V contractor, who provides an independent assessment of the functionality and performance of the release. The IATO supports IV&V testing at the operational centers for several weeks following successful completion of RRR. The IATO clarifies ECS design, implementation, integration, and test issues and provides test support personnel to the

IV&V contractor. Additionally, the M&O organization supports the IATO and IV&V contractor, as necessary, during IV&V testing, when the release is in a pre-operational state. After IV&V testing, the ESDIS Integration Team integrates ECS with other EOSDIS components by conducting key integration and certification tests (KIITs). Following these KIITs, the IV&V contractor performs EOSDIS certification testing. Prior to EOS spacecraft launch, the M&O Flight Operations Team supports operational readiness tests, e.g., mission simulations and data flow and end-to-end tests.

ECS verification activities continue during ongoing operations. Nonconformance resolutions or corrections that must be implemented prior to the next release are verified during the M&O phase. Flight mission verification activities that utilize the operational ECS also occur during the M&O phase. EOS flight mission readiness reviews, including the Ground System Operational Readiness Review and several flight assurance reviews, are supported by the ECS contractor during this phase.

3.7 Verification Levels

There are six levels of verification utilized in verifying ECS hardware and software components: unit testing, segment I&T, system I&T, acceptance testing, IV&V testing, and operational testing. These levels are shown in Figure 3-1 and Table 3-1. The first four verification levels, i.e., unit testing, segment I&T, system I&T, and acceptance testing, occur during the ECS development cycle and are performed by the ECS contractor. IV&V testing occurs shortly after RRR, at the beginning of the M&O phase, and is accomplished by the IV&V contractor with IATO support. Operational testing occurs during the ongoing M&O phase and is performed by the ECS contractor. However, verification of certain system enhancements, such as new capabilities for specific flight missions, also involves external organizations. In addition to the six verification levels, regression testing is also used in verifying the ECS.

3.7.1 Unit-Level Testing

The purpose of unit testing is to demonstrate the correctness and consistency of newly developed, heritage, and COTS software, as well as the performance of all COTS hardware, at the unit level. Unit testing is performed by the Segment Development organizations and the Integrated Logistics Support (ILS) part of the M&O organization.

The Segment Development organizations verify CSUs and CSCs, which are the basic software building blocks of ECS releases. This software consists of newly developed and heritage software, and those COTS products incorporated into segment software to satisfy requirements. Newly developed and heritage software is tested at the unit level for typographical, syntactical, and logical coding errors.

The COTS software products that become part of segment software are specified by the Segment Development organizations to meet certain functional and performance requirements. These COTS products are verified at the EDF for compliance with vendor specifications within the context of segment requirements. General adherence to these requirements are initially verified by the ILS and later by the Segment Development organizations prior to their aggregation with other software modules at the unit level. In this way vendor noncompliance with COTS

requirements is communicated to the vendor early in the release life cycle. The functionality of COTS software and its inter-operability with the custom-designed software are verified. Only complete, tested CSUs and CSCs are delivered to the Segment I&T organizations, unless upgrades or corrections are required. Unit testing is documented in SDFs.

COTS hardware and those COTS software products used in the hardware support environment, such as operating systems, are essentially part of the platforms provided to the operational centers, i.e., the DAACs, EOC/ICC, and SMC for use in their operations. The ILS organization performs unit-level verification of these COTS products following installation. This verification activity, which is monitored by the IATO, demonstrates that the equipment and associated software are properly installed and integrated with each other, that they meet specific ECS technical requirements, and that they meet the general regulations applying to the acquisition of Automated Data Processing Equipment (ADPE). ADPE that is covered by General Services Administration acceptance criteria is verified at the unit level in accordance with those criteria.

Unit-level verification of COTS hardware and those COTS software products used in the hardware support environment, consists of three parts:

- COTS hardware inspections and demonstrations, which verify that all hardware components are operational
- COTS software demonstrations, which verify that all COTS software components are operational and configured properly
- A COTS hardware/software interface demonstration, which verifies the inter-operability and functionality between ECS COTS hardware and software

Additionally, performance tests are conducted for all specified performance parameters, and reliability/maintainability data are verified insofar as practicable by inspection and analysis.

3.7.2 Segment-Level Integration and Test

Segment I&T activities are performed by the Segment I&T organizations. Due to the uniqueness and criticality of FOS in commanding and controlling EOS spacecraft and instruments, FOS verification activities are emphasized in this subsection.

During segment I&T, verified components from unit-level testing, i.e., CSUs, CSCs, and COTS software, data bases, and segment hardware, are aggregated into segment threads. The threads are individually verified and then incrementally integrated into segment builds. These builds are evaluated for correctness, consistency, and completeness with respect to approved segment requirement specifications. Builds are combined with other builds and threads to create higher level builds and a gradual buildup of segment capabilities. The Segment I&T organizations verify all segment threads and builds within their respective segments. The Segment I&T process verifies that the segments satisfy ECS Level 4 requirements, including intra-segment interfaces.

The FOS Development organization creates standard data sets for exercising scheduling, commanding, and monitoring functions. The EOC/ICC maintains standard data sets to verify all spacecraft telemetry formats and all command and telemetry functions for non-complex and complex instruments that are operated from the EOC/ICC. (Complex instruments are those instruments capable of variable pointing.) When external data from simulators or from the actual

spacecraft and instrument hardware become available, they will be used to develop standard data sets as well. The EOC/ICC conducts separate internal interface tests with other portions of the ECS over the ESN. The EOC/ICC uses test data and simulated interfaces, as necessary, to conduct separate interface tests with the Network Control Center (NCC), EDOS, and other external systems over Ecom. The IST is generally tested as a subset of the EOC/ICC since they share many functions. However, ISTs will also be tested for compliance with toolkit standards and for their interfaces with the EOC/ICC.

There are two documents against which segment tests are verified: the Segment/Element Requirements Specification (DID 304/DV1) and the ECS Internal ICDs (DID 313/DV3) for ECS intra-segment interfaces. Furthermore, there are three primary documents that describe segment integration and test planning, procedures, and reporting: the Segment/Element Integration & Test Plan (DID 319/DV1), Segment/Element Integration & Test Procedures (DID 322/DV3), and Segment/Element Integration & Test Reports (DID 324/DV3). Section 4, Verification Reporting, provides further details on these three segment I&T documents.

3.7.3 System-Level Integration and Test

System integration and test activities are performed by the System I&T organization. In general, the System I&T organization starts with the highest level builds at the segment level and uses them as system threads. These threads, which might be derived from different segments, are combined into system builds, which are then tested. These builds are aggregated with other system threads and/or other tested system builds into higher-level system builds, which are also tested. This process is repeated for all system builds until ultimately the complete release is integrated and tested. System test threads functionally verify the operational threads previously used for lower level testing. Near the completion of system I&T at the EDF, the then-current version of the release is installed and checked at operational centers to provide confidence that the capabilities of the release are consistent between the operational centers and the EDF.

The System I&T process verifies that the release satisfies ECS Level 3 requirements including ECS internal, inter-segment, interfaces. Internal interfaces are tested with ECS software and hardware where available. Informal verification of external interfaces using simulators or locally devised tests is accomplished during the System I&T phase to reduce the risk of acceptance testing with immature external systems. COTS conformance to Level 3 requirements is under continuous verification as the evolving ECS undergoes verification performed at the system thread and build levels. The IATO witnesses System I&T activities and monitors test progress.

There are two primary documents against which system tests are verified: the ECS Requirements Specification (DID 216/SE1) and Interface Requirements Documents (DID 219/SE1). Additionally, there are three primary documents that describe system integration and test planning, procedures, and reporting: the ECS System Integration & Test Plan (DID 402/VE1), ECS System Integration & Test Procedures (DID 414/VE1), and ECS System Integration & Test Report (DID 405/VE3). Section 4, Verification Reporting, provides further details on these three system I&T documents.

3.7.4 Acceptance-Level Testing

Acceptance testing involves preparation at the EDF prior to CSR, and formal testing at the operational centers after CSR. Testing at the operational centers provides the IATO with the ability to test utilizing the unique operational configuration of each operational center. This on-site test capability, together with the emphasis on science and operational scenarios, means that acceptance testing is performed in a more "real-world" environment than any of the verification levels described in the preceding subsections.

Most Level 3 requirements are verified at the acceptance level through formal release acceptance testing at ECS centers. It is possible, however, that some Level 3 requirements will be verified at the acceptance level by analyzing the results of segment I&T or system I&T at the EDF. This process would reduce the amount of time and resources involved in release acceptance testing at the ECS centers. The reason for this is that the IATO would only need to analyze the results of segment I&T or system I&T for these requirements in order to satisfy acceptance criteria. This analysis would be done at the EDF, and the requirements would not be verified during formal acceptance testing at the ECS centers, thereby saving time and resources. The type of requirements that are likely candidates for this approach are those that are confined to one segment and difficult to test during formal acceptance testing. In order to implement this approach, the IATO performs the following tasks:

- Consults with the segment and system I&T organizations and the GATT to identify candidate Level 3 requirements during the preparation of segment I&T and system I&T.
- For candidate requirements verified at segment I&T, ensures that the Level 3 requirements are completely satisfied within one segment.
- For candidate requirements verified at segment I&T, ensures that the Level 3 requirements are traceable to Level 4 requirements.
- For candidate requirements verified at segment I&T, works with the appropriate Segment I&T organization to ensure that the Segment/Element Integration & Test Plan (DID 319/DV1) and Segment/Element Integration & Test Procedures (DID 322/DV3) identify those Level 4 requirements that map to candidate Level 3 requirements.
- For candidate requirements verified at system I&T, works with the System I&T organization to ensure that the ECS System Integration & Test Plan (DID 402/DV1) and ECS System Integration & Test Procedures (DID 414/VE1).
- Ensures that the ECS System Acceptance Test Plan (DID 409/VE1) and ECS System Acceptance Test Procedures (DID 411/VE1) identify those Level 3 requirements that are verified by analysis of segment I&T or system I&T results.
- Witnesses the execution of the relevant portions of segment I&T or system I&T.
- Documents nonconformances.
- Works with the Segment I&T or System I&T organizations to ensure that the relevant I&T results are included in the Segment/Element Integration & Test Reports (DID 324/DV3) or the ECS System Integration & Test Report (DID 405/VE3).

- Ensures that the ECS System Acceptance Test Report (DID 412/VE2) includes the analysis of segment I&T or system I&T.

Unlike unit testing, segment I&T, and system I&T, formal acceptance testing entails evaluating many functional capabilities and system performance as efficiently as possible with error isolation secondary. Prior to CSR, the IATO conducts acceptance test preparation at the EDF as the System I&T organization completes individual portions of their integration and test activities. In the final phases of system I&T prior to CSR, the IATO conducts informal walkthroughs of the acceptance test procedures at the EDF. In the event that any nonconformances are observed, they will be formally filed and addressed at the CSR.

Immediately after CSR, a checkout of the testing environment at operational centers is accomplished in preparation for *formal* acceptance testing at these centers. This pre-acceptance test checkout is a readiness exercise to provide confidence that the release is ready for formal acceptance testing at each center. At least 3 weeks prior to conducting the formal release acceptance tests, the IATO notifies the ECS I&AT Manager and IV&V contractor so they can witness these tests as desired. Formal acceptance testing is conducted by the IATO with GATT oversight upon completion of the CSR and center checkout.

The acceptance testing process verifies the content of operational procedures and user's guides as they relate to the release under test. This process also verifies the extent to which the release satisfies Level 3 and external interface requirements and emphasizes testing of high risk and potentially weak areas. For those external systems that will be either immature or unavailable when required, simulated external systems and test data will be used to test the interfaces. Operational external systems will be used to test external interfaces only if the external systems are available for testing. The functionality and performance of platforms at ECS centers are also verified by the IATO during release acceptance testing.

COTS product conformance to Level 3 requirements undergoes final verification as the evolving ECS undergoes release acceptance testing. Acceptance testing of all hardware and associated COTS software and validation of adherence of delivered ECS systems to Open Systems standards are based on allocated performance requirements and inspection and analysis of vendor specifications.

The IATO plans and executes acceptance tests as a surrogate for the GATT with the GATT involved. The IATO verifies configuration status, identifies nonconformances, tracks anomaly and nonconformance resolution, analyses test results, plans and conducts retesting required by configuration updates, and documents test findings in test reports. If possible, local M&O personnel and DAAC customer operations personnel serve as active test participants during formal release acceptance testing, which provides them with early visibility into the new release and hastens the smooth transition of the release into operations. This M&O involvement in, and familiarity with, ECS hardware and software prior to operations should greatly enhance the M&O organization's effectiveness, productivity, and responsiveness.

Formal acceptance testing occurs at each applicable center, depending on the content of the release. Releases A, B, C, and D are scheduled for installation at all operational centers, i.e., the EOC/ICC, and SMC at Goddard Space Flight Center (GSFC), and the eight DAACs at GSFC, Langley Research Center (LaRC), Marshall Space Flight Center (MSFC), the Earth Resources

Observation System (EROS) Data Center (EDC), the Oak Ridge National Laboratory (ORNL), the Jet Propulsion Laboratory (JPL), the National Snow and Ice Data Center (NSIDC), and the Alaska Synthetic Aperture Radar (SAR) Facility (ASF). However, installation of a release, such as Release A, at some of these centers might be delayed for several months. For those centers where release installation is delayed, acceptance testing might be further delayed until the next formal release is installed.

For all formal releases, two phases of acceptance testing at the operational centers are planned: center-specific testing, where the focus is on each individual center, and "all-up" testing, where all applicable centers are tested simultaneously as a unit. In order to minimize the total time required to accomplish overall acceptance testing for these releases, several teams perform center-specific testing at the same time. DAAC-specific approaches relating to acceptance testing are included in the ECS System Acceptance Test Procedures (DID 411/VE1).

The following is a possible schedule for Release B acceptance testing at the operational centers. One test team performs center-specific acceptance testing of the release at the GSFC DAAC, EOC/ICC, and SMC. At the same time another team tests the release at the LaRC DAAC. Due to the complexity and criticality of flight operations as well as the spacecraft and instrument control systems, and since the FOS functions somewhat separately from the remainder of the ECS, the EOC/ICC is tested for an extended period, i.e., until the start of the "all-up" testing, described below. Verification of the SMC also occurs during this same extended period by virtue of the control functions performed by the SMC in configuring the environments and maintaining system management information for each center as part of center-specific testing.

As each center-specific test is completed, a post-test meeting is held to evaluate results. The participating members formulate a quick-look report upon test completion and forward it to the rest of the GATT via electronic mail. Nonconformances are recorded in the NRCA system for everyone’s review. The nonconformance process is further described in Sections 4.3.1 and 4.3.2.

Once testing is complete at the GSFC and LaRC DAACs, a second set of center-specific testing of the release is then conducted at the MSFC, EDC, and ORNL DAACs. During this time, testing of the EOC/ICC and SMC continues at GSFC. After the completion of center-specific testing at the MSFC, EDC, and ORNL DAACs, a third set of center-specific testing occurs at the JPL, NSIDC, and ASF DAACs. Testing of the EOC/ICC and SMC continues at GSFC.

Upon completion of all center-specific testing, the test teams are dispersed so there is representation at each center for "all-up" acceptance testing. This testing is executed to verify interfaces and interoperability among the DAACs, EOC, ICCs, and system management services and to ensure that the entire release functions and performs as required. Following the "all-up" testing, the GATT assesses the acceptability of the release based on the results of acceptance testing, which are presented at the RRR by the IATO. The ESDIS Deputy Project Manager for ECS decides on the acceptability of the release.

There are two primary documents against which acceptance tests are verified: the ECS Requirements Specification (DID 216/SE1) and Interface Requirements Documents (DID 219/SE1). There are also four primary documents that describe acceptance testing management, planning, procedures, and reporting: the Acceptance Testing Management Plan, (DID 415/VE1), ECS System Acceptance Test Plan (DID 409/VE1), ECS System Acceptance Test Procedures

(DID 411/VE1), and ECS System Acceptance Test Report (DID 412/VE2). Section 4, Verification Reporting, contains further details on these four acceptance testing documents.

3.7.5 Independent Verification and Validation (IV&V) Testing

Upon completion of the RRR, the IV&V contractor provides an independent assessment of the functionality and performance of ECS releases. This IV&V testing, which is pre-operational testing and performed at ECS centers, validates ECS Level 3 requirements. The IV&V contractor also tracks and supports the resolution of nonconformances identified during this testing. The IATO, which serves as the ECS contractor's primary point-of-contact for the IV&V contractor, supports IV&V testing at ECS centers. The IATO ensures that the IV&V contractor has access to all ECS contractor test activities and technical information, such as acceptance test results and nonconformance reports and resolutions. Additionally, the IATO coordinates personnel, facilities, and equipment support in the resolution of ECS nonconformances identified during IV&V contractor testing.

3.7.6 Operational Testing

Operational testing, in the context described herein, refers to post-IV&V testing on a formal release. It is performed independent of the ECS development cycle, although modifications to the operational system resulting from this testing must be incorporated into the next release. The objective of operational testing is to verify that the ECS meets system-level requirements in the operational environment. There are two categories of operational testing:

- Formal, pre-planned testing needed to support an EOS mission
- Testing that is not pre-planned and does not support a specific mission, such as testing emergency patches and integrating enhancements

Several formal, pre-planned testing activities follow IV&V testing of the ECS and precede the launch of an EOS spacecraft. They include the integration of the ECS with other EOSDIS components, EOSDIS certification testing, and operational readiness testing. The ESDIS Integration Team performs EOSDIS integration, and the IV&V contractor conducts the EOSDIS certification tests. The Flight Operations Team supports the spacecraft contract with operational readiness testing, including mission simulations and final data flow and end-to-end tests, which exercise as many operational functions as feasible.

Problems with a release might arise after operations for the release has begun. Such nonconformances would likely be resolved in one of three ways:

- For time-critical problems, an emergency patch would be implemented and a change made to the operational release.
- For problems that can wait until the next scheduled release for resolution, a change would be implemented only as part of the next scheduled release, i.e., the operational release would not be changed.
- Upgrades, which are required prior to the next release but are not considered emergencies, would be implemented prior to the next release. Such upgrades might contain substantial capabilities.

Emergency patches should occur infrequently, but the time period required for their development, verification, and integration into the operational release are not known in advance. Although the time and resources expended on emergency patches might be minimal, the patches are of such importance that they require implementation as soon as possible. Assuming an emergency patch is successfully integrated into the operational release, it would then incorporated into the next scheduled release and verified and delivered as an integral part of that next release. The M&O organization verifies emergency corrections to the operational system. When changes are made to the operational release, regression testing is used to verify that the changes do not adversely impact the release as a whole (see Subsection 3.7.7, Regression Testing). The IATO assists in providing benchmark regression tests and testing procedures to verify operational performance and functionality of approved changes and enhancements implemented during the M&O phase.

At each operational center, selected positions or teams are responsible for the verification of corrections, and enhancements during the M&O phase. At the DAACs, Sustaining Engineering personnel verify system upgrades, both hardware and software, and maintain and update test procedures and data bases. Also at the DAACs, the AIT assists in verifying that science algorithms operate properly in the PGS production environment. In order to minimize adverse impacts on DAAC operations, DAAC-specific approaches, which are included in the ECS System Acceptance Test Procedures (DID 411/VE1), will be utilized for conducting on-site verification activities while supporting operations.

After the launch of the first EOS spacecraft, all I&T activities can be conducted in parallel with normal operations. Operations Support personnel, the Flight Operations Team, and the instrument operations team can perform tests on EOC/ICC operational equipment and interfaces to ensure proper operation and to help isolate problems.

3.7.7 Regression Testing

Regression testing, which supplements the verification level hierarchy described in the preceding subsections, is performed at any time after unit testing has been completed to ensure that existing software is not adversely affected by modified or new software. The Segment Development organizations, the Segment I&T organizations, the System I&T organization, the IATO, and the M&O organization independently plan, conduct, and analyze regression tests. These tests are used to verify that a new release, software change, or operational enhancement does not adversely impact the unchanged portions of the existing configuration.

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4. Verification Reporting

4.1 Verification Documentation

Several verification documents describe the overall ECS verification methodology and processes, while others are tailored to the segment I&T, system I&T, and acceptance test levels. These documents are briefly described in the following subsections. For segment I&T, system I&T, and acceptance testing, there are corresponding plans, procedures, and reports documents as described in the following sections. The reports documents are delivered after all activities for the corresponding verification level have been completed.

4.1.1 Overall Test Matrix

A test matrix summarizing all tests performed at the system I&T and acceptance testing levels can be generated from the RTM data base. This matrix, which is contained in the Verification Specification (DID 403/VE1), maps system-level requirements to tests performed at the system I&T and acceptance testing levels. A test matrix mapping all tests performed at the segment I&T level can also be generated from the RTM data base.

4.1.2 General Verification Documents

There are six deliverable documents that apply to the overall verification process:

- Verification Plan (DID 401/VE1). This document presents the overall test, review, and analysis effort for the ECS project, describes the verification activities associated with each ECS life cycle phase and level of verification, delineates the responsibilities of, and interfaces among, those organizations that verify the ECS, and describes verification reporting activities and the ECS nonconformance system.
- Verification Specification (DID 403/VE1). This document contains the Overall Test Matrix for the ECS project. It maps system-level requirements to the tests specified in the ECS System Integration & Test Plan (DID 402/VE1) and the ECS System Acceptance Test Plan (DID 409/VE1). The Verification Specification thus provides a system-level mapping of requirements to tests that will be performed for each ECS release.
- Procedure for Control of Unscheduled Activities During Verification (DID 404/VE1). This document describes the mechanism for controlling, documenting, and approving all activities not part of an approved verification procedure. It also documents real-time decision-making mechanisms to expedite continuation/suspension of testing after a nonconformance.
- Maintainability Demonstration Plan (DID 511/PA1). This document is the plan of the maintainability demonstration tests used to verify the capability of the planned maintenance activities to meet the required operational availabilities/mean down times. It also identifies the test specification requirements of all Maintainability Demonstration Test Plans (DID 512/PA1).

- Maintainability Demonstration Test Plans (DID 512/PA1). This document contains the test plans for each of the demonstration tests included under the Maintainability Demonstration Plan (DID 511/PA1).
- Maintainability Demonstration Test Reports (DID 519/PA3). This document contains the results of each demonstration test included under the Maintainability Demonstration Plan (DID 511/PA1).

4.1.3 Segment Integration & Test Documents

There are three segment integration and test documents that are required deliverables for the three ECS segments, i.e., CSMS, SDPS, and FOS:

- Segment/Element Integration & Test Plan (DID 319/DV1). This document presents the process for integrating units into segment-level builds and for verifying compliance with the Segment/Element Requirements Specification (DID 304/DV1). Additionally, the plan describes the need for special resources, identifies responsible organizations, and shows how all segment requirements have been satisfied by the integrated segments.
- Segment/Element Integration & Test Procedures (DID 322/DV3). This document contains step-by-step procedures to accomplish segment I&T and test intra-segment interfaces. It also defines the specific objectives, event sequences, support requirements, configuration identification, and test article information for segment I&T.
- Segment/Element Integration & Test Reports (DID 324/DV3). This document contains a test log, the results of each test, and an overall analysis. Any deficiencies, limitations, or constraints detected during testing, as well as any deviations from the segment I&T procedures, are also described.

4.1.4 System Integration & Test Documents

There are three system integration and test documents that are required deliverables:

- ECS System Integration & Test Plan (DID 402/VE1). This document presents the process for integrating top-level segment and system threads into system-level builds. Additionally, the plan describes the need for special resources, identifies responsible organizations, and shows how all system requirements have been satisfied by the integrated system.
- ECS System Integration & Test Procedures (DID 414/VE1). This document contains step-by-step procedures to accomplish system-level tests to demonstrate ECS functional capability and test the system interfaces. It also defines the specific objectives, event sequences, support requirements, configuration identification, and test article information for system I&T.
- ECS System Integration & Test Report (DID 405/VE3). This document contains a test log, the test results, and an overall analysis. Any deficiencies, limitations, or constraints detected during testing, in addition to any deviations from the system I&T procedures, are also described.

4.1.5 Acceptance Testing Documents

There are five acceptance testing documents that are required deliverables:

- Acceptance Testing Management Plan (DID 415/VE1) (ATMP). The ATMP discusses the organization, responsibilities, methodology, and coordination efforts of the IATO. The overall process of acceptance test preparation, conduct, and review is also described.
- ECS System Acceptance Test Plan (DID 409/VE1). This document presents the plan for conducting formal release acceptance testing and describes acceptance criteria, test scenarios, and lower-level acceptance tests.
- ECS System Acceptance Test Procedures (DID 411/VE1). This document contains step-by-step procedures for the preparation, conduct, and analysis of formal acceptance tests, including specific objectives, event sequences, support and facility requirements, configuration identification, constraints, test article identification, special instructions for recording equipment, and nonconformance reporting.
- ECS System Acceptance Test Report (DID 412/VE2). This report documents the results of acceptance testing and provides recommendations for such items as software redesign or specification revision. It also contains a test log and analysis as well as the name, number, and results of each test performed and describes any deviations from the acceptance test procedures.
- Acceptance Data Package (DID 535/PA1). This document contains final system configuration information, results of the acceptance testing program, test logs, list of open items, instruction material for maintenance, and operating manuals.

4.2 Informal Reporting

Meetings are frequently held among the various ECS contractor verification organizations, including the IATO, system and segment I&T organizations, and Quality Office, to relay information, discuss verification issues and plans, and present relevant ideas. These meetings have helped test and associated personnel become acquainted with one another and have formed the foundation of understanding among verification organizations. Topics often discussed include the methodology for ECS verification and the contents of the documents described in Subsection 4.1, Verification Documentation. Additionally, test personnel gather and exchange information on, attend demonstrations of, and discuss advantages and disadvantages of, various test tools. Periodic meetings have also been held between the GATT and key ECS contractor test personnel to discuss verification issues, test planning progress, and documentation status.

The IATO and System I&T organization are both components of the SI&P. As such, both of these organizations coordinate with SI&P management on test-related schedules, activities, and documentation and provide technical information and recommendations dealing with verification issues. Similarly the Segment I&T organizations coordinate with their respective segment managers on verification-related issues and documentation.

The verification organizations coordinate often to successfully verify the ECS. During unit testing, the Segment Development organizations develop the components of segment-level threads, which are then tested and integrated by the respective Segment I&T organizations. Thus

these groups work closely together so that the Segment I&T organizations attain a firm understanding of the components that comprise segment-level threads. The Segment and System I&T organizations meet regularly during test executions since system I&T begins long before the last segment-level builds are tested. Thus System I&T must be aware of the progress, status, and nonconformances associated with segment I&T. Similarly, the IATO needs to know the status of system I&T, since acceptance test preparation begins shortly after the start of system I&T. The IATO also works with the Segment I&T organizations for planning and witnessing segment-level tests and analyzes test results for satisfaction of acceptance criteria associated with Level 3 requirements. Additionally, the IATO collaborates with the Science Office on obtaining scenarios, developed by the science community, for acceptance testing. The IATO also interfaces with the IV&V contractor to provide technical information and documentation developed by the ECS contractor and to support IV&V testing of ECS releases.

The Quality Office coordinates with all testing organizations to verify that test plans and procedures and standards are followed, to review and track nonconformances, and to monitor and witness tests. The Segment and System I&T organizations and the IATO interface with the CM organization to retrieve test plans, procedures, and any previous test reports; the software and hardware configuration to be tested; and test data sets, software, and hardware configuration information, including test tools, needed to perform the testing. The M&O collaborates with the Segment and System I&T organizations to support and system integration testing and planning. The M&O organization also works with the IATO in supporting acceptance test planning, operational scenario definition for acceptance testing, and conduct of acceptance testing. The GATT oversees the activities of the IATO and coordinates often with the IATO and System I&T organization to discuss test issues and methodology, review requirements testability, select test tools, and establish test schedules.

4.3 Nonconformance Reporting

This section describes the nonconformance reporting and corrective action (NRCA) system and the process for filing, reviewing, and closing nonconformances.

4.3.1 Nonconformance Reporting Overview

The NRCA system is a closed-loop system to control problems identified in documentation, software, and hardware. A nonconformance, often called a problem, discrepancy, anomaly, fault, error, failure, or malfunction, is defined as a condition of any hardware, software, material or service in which one or more characteristics do not conform to requirements of hardware, software, safety, Reliability, Maintainability, and Availability (RMA) or documentation. The NRCA system supports the development, integration and test, acceptance testing, implementation, and maintenance and operation of the ECS. This system tracks nonconformances, assigns priorities, records dispositions, identifies the version of the product in which they are corrected, notifies the originator of current status, and produces management reports. Corrective action is a general name for the process by which nonconformances are resolved and controlled. Nonconformances fall into two categories: discrepancies and malfunctions. A discrepancy is a departure from specification that is detected during inspection or process control testing, etc., while the hardware or software is not functioning or operating. A malfunction is a departure from the specification that is discovered in the functioning or

operations of the hardware or software. The ECS Project Instruction for Nonconformance Reporting and Corrective Action (NRCA) (PI-QO-1-009) describes the nonconformance reporting process in further detail.

4.3.2 Nonconformance Processing

Nonconformance reports may be filed against any product in any phase of the ECS life cycle by anyone associated with the project. During software development and I&T, software problems are identified as discrepancies and are resolved and managed internally by the development and test activity. If the discrepancy is in the code or a data product, those responsible for segment, systems, and acceptance test activities develop tests to ensure that the problem is satisfactorily corrected. In addition, regression testing is conducted to make sure that no new problems have been introduced by the fix. CM tracks the product changes and versions that result from correcting discrepancies. Some discrepancy reports contain proposed requirement changes. These reports result in the opening of a change request and are handled by the CM process and acted upon at the Configuration Control Board (CCB) meetings. The Quality Assurance representatives responsible for monitoring and witnessing test activities ensure proper tests are conducted against the discrepancy reports. Both in-process audits and formal audits are conducted against these activities.

The reporting of malfunctions is initiated when the software is used with the ECS hardware any time after the beginning of acceptance testing activity. The NRCA system is used to inform users of the code about malfunction and to assure that the nonconformances are corrected and not overlooked. When an inconsistency is discovered, the individual (i.e., engineer, user, or DAAC representative) identifying the problem documents what he/she believes to be the preliminary problem. Once the problem has been identified, it is entered in the NRCA system. The information will be forwarded to the segment manager or technical lead for further analysis and review. When the initial resolution is complete, the problem is submitted to the Review Board for disposition. In the case of an emergency fix, the problem is sent with documentation to the applicable engineering or maintenance organization where it is evaluated. If the disposition is allowed, the Review Board will sign off on the problem, and the process will continue with the appropriate verification level. However, if the problem is assigned to a CCR, it will be submitted to the CCB and progress through the CM process. If the problem is approved by the board, the CM process for malfunction reporting will begin. The CM process involves determining the cost, if any, for repairing the problem, whether the repair will have a negative or a positive impact on the scheduling for the project, and whether any changes to the specifications need to be addressed. Last, a determination is made regarding the segment and/or limited classification of the action. If the problem is given a Class 1 code, then approval must come from NASA. A Class 2 code can be approved internally. The closeout report is signed by the Review Board Chairperson and submitted to NASA for authorized closure. GSFC Performance Assurance Office is notified of nonconformance reports and their status through several required reports. Specifically, the Quality Office will deliver contract deliverables identifying nonconformances throughout the project.

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5. Configuration Management

Configuration Management defines the process for managing releases and toolkits to ECS centers and provides the means for storing, maintaining, tracking, and retrieving verification items in a controlled manner.

5.1 Test Items Under Configuration Control

ECS test documents, software and hardware configurations under test, test data sets, and software and hardware used for testing are maintained in the appropriate CM or Data Management (DM) library. All changes to these items, including the addition of new components at all levels of integration and the implementation of corrective action, are performed in accordance with the Configuration Management Plan (DID 102/MG1), Configuration Management Procedures (DID 103/MG3), and Data Management Plan (DID 104/MG1).

Once the following test items are finalized, they are stored and baselined by the CM organization in the segment I&T, system I&T, or acceptance testing portion of the controlled CM or DM library. The required items are retrieved from the CM library when needed to perform the various verification activities. These items include:

- Verification documents, including test plans, procedures, and reports. They are used by the Segment I&T and System I&T organizations and the IATO to provide direction, procedures, and other relevant information about the segment I&T, system I&T, and acceptance testing to be performed.
- Test data sets, software, test tools, hardware configuration, and test environment. They are used by the Segment I&T and System I&T organizations and the IATO to perform verification activities.
- Unit-tested components, i.e., CSUs, CSCs, data sets, segment hardware configuration, and associated COTS software. They are verified and integrated by the Segment I&T organizations during segment I&T.
- Segment-verified threads and builds. They are integrated into system-level builds, and ultimately a system-level release, by the System I&T organization during system I&T.
- Integrated system-level release. The release is verified by the IATO during formal acceptance testing at ECS centers.
- Acceptance criteria. Each criterion serves as the basis for determining if the hardware and/or software used to satisfy each Level 3 requirement can be accepted by the government, i.e., whether the hardware and/or software that the IATO verifies during acceptance testing passes or fails the acceptance criteria.
- Nonconformance reports. The Segment I&T and System I&T organizations, the IATO, and the IV&V contractor require nonconformance information for their verification activities.

Upon completion of testing, the CM organization obtains and retains test outputs, e.g., test logs, data, and modified procedures, and distributes copies for test analyses.

5.2 Release Management

The three segment CCBs, assisted by the SI&P and CM organization, control changes to their respective product development libraries during the implementation phase of each release. The ECS contractor CCB, which is at a higher level than the segment CCBs, takes over the change control role as the product handover to acceptance testing occurs. Upon completion of the CSR, the release is shipped from the CM master library at the EDF to the IATO portion of the CM library at the ECS centers. To reduce overhead on communication links, major (bulk) software releases from the CM master library are distributed to each affected ECS center via removable media. The released software is left on-line to represent the status of the installed configuration. Minor software releases can be distributed directly via system management services to each Local System Management (LSM) process at the centers for staging and distribution. In addition, each center has unique system interfaces supported by their own CM library. The CCBs at each center maintain the center-unique CM libraries, whose contents are shipped to the EDF CM master library for archival and general reference.

5.3 Configuration Audits

The Configuration and Data Management organization supports FCAs and PCAs during acceptance testing. Each configuration audit accomplishes the following:

- The as-built configuration shipped to the ECS centers is compared to the final configuration at the EDF. Any differences between the center and EDF configurations are documented in the audit report.
- The as-built configuration shipped to the centers is compared to the design specifications. Any differences between the technical description contained in each specification and the shipped configuration is documented in the audit report.
- The acceptance testing documentation is reviewed to ensure that all Level 3 requirements have been verified. Any requirements that either were not tested or failed testing are documented in the audit report.
- Nonconformances identified during testing are reviewed to ensure that each nonconformance has been either closed or rescheduled for the next release. Any nonconformances that are unresolved are documented in the audit report.

Abbreviations and Acronyms

ADPE	Automated Data Processing Equipment
AERO	EOS Aerosol Mission
AIT	Algorithm Integration Team
ALT	EOS Altimeter Mission
AM	EOS Morning Crossing Mission
ASF	Alaska SAR Facility
ATMP	Acceptance Testing Management Plan
BOD	Beneficial Occupancy Date
CASE	Computer Aided Software Engineering
CAST	Computer Aided Software Test
CCB	Configuration Control Board
CCR	Configuration Change Request
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CERES	Clouds and Earth’s Radiant Energy System
CHEM	EOS Chemistry Mission
CM	Configuration Management
COTR	Contracting Officer's Technical Representative
COTS	Commercial Off-the-Shelf
CRR	Capabilities and Requirements Review
CSC	Computer Software Component
CSMS	Communications and System Management Segment
CSR	Consent to Ship Review
CSU	Computer Software Unit
DAAC	Distributed Active Archive Center
DCN	Document Change Notice
DID	Data Item Description
DM	Data Management
DV	Development

Ecom	EOS Communications
ECS	EOSDIS Core System
EDC	EROS Data Center
EDF	ECS Development Facility
EDOS	EOS Data and Operations System
EOC	EOS Operations Center
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EP	Evaluation Package
EPERR	Evaluation Package Evaluation Readiness Review
EROS	Earth Resources Observation System
ESDIS	Earth Science Data and Information System
ESN	EOSDIS Science Network
ETR	Element Test Review
ETS	EOSDIS Test System
FCA	Functional Configuration Audit
FOS	Flight Operations Segment
GATT	Government Acceptance Test Team
GSFC	Goddard Space Flight Center
GUI	Graphical User Interface
I&AT	Integration and Acceptance Test
I&T	Integration and Test
IATO	Independent Acceptance Test Organization
ICC	Instrument Control Center
ICD	Interface Control Document
IDR	Incremental Design Review
ILS	Integrated Logistics Support
IR-1	Interim Release-1
IST	Instrument Support Terminal
IV&V	Independent Verification and Validation
JPL	Jet Propulsion Laboratory
KIIT	Key Integration and Certification Test

LaRC	Langley Research Center
LIS	Lightning Imaging Sensor
LSM	Local System Management
M&O	Maintenance and Operations
MG	Management
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCC	Network Control Center
NRCA	Nonconformance Reporting and Corrective Action
NSIDC	National Snow and Ice Data Center
OP	Maintenance and Operations
ORNL	Oak Ridge National Laboratory
PA	Product Assurance
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PGS	Product Generation System
PI	Project Instruction
PM	EOS Afternoon Crossing Mission
PMR	Project Management Review
QO	Quality Office
RDR	Release Design Review
RIR	Release Initiation Review
RIT	Real Time Integrated Testbed
RMA	Reliability, Maintainability, and Availability
RRR	Release Readiness Review
RTM	Requirements & Traceability Management
SAR	Synthetic Aperture Radar
SCF	Science Computing Facility
SD	Software Development
SDF	Software Development File
SDPS	Science Data Processing Segment
SDR	System Design Review

SE	System Engineering
SI&P	System Integration and Planning
SORR	Segment Operational Readiness Review
SRR	System Requirements Review
SSIM	Spacecraft Simulator
TRMM	Tropical Rainfall Measuring Mission
TRR	Test Readiness Review
VE	Verification

Glossary

acceptance testing	Verification that is conducted to determine whether a formal release satisfies its acceptance criteria and that provides the Government with information for determining whether the release should be accepted. Acceptance testing can also be performed on other ECS deliverables, such as toolkits, science algorithm integration, and unit-level verification of COTS products.
analysis	Technical or mathematical evaluation based on calculation, interpolation, or other analytical methods.
build	An assemblage of threads to produce a gradual buildup of system capabilities.
demonstration	Observation of the functional operation of the verification item in a controlled environment to yield qualitative results without the use of elaborate instrumentation, procedure, or special test equipment.
inspection	The visual, manual examination of the verification item and comparison to the applicable requirement or other compliance documentation, such as engineering drawings.
integration	The orderly progression of combining lower level software and/or hardware items to form higher level items with broader capability.
segment	One of the three functional subdivisions of the ECS, i.e., FOS, SDPS, and CSMS.
test	A procedure or action taken to determine under real or simulated conditions the capabilities, limitations, characteristics, effectiveness, reliability or suitability of a material, device, system, or method.
thread	A set of components (software, hardware, and data) and operational procedures that implement a function or set of functions.
validation	The process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements.
verification	The process of evaluating the products of a given development activity to determine correctness and consistency with respect to the products and standards provided as input to that activity.

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